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THREAD GAGE MANUFACTURE

JONES & LAMSON MACHINE COMPANY

ORDNANCE RESEARCH PROJECT OD-49

NDRC CONTRACT OEMsr-497

MONOGRAPH
ON MANUFACTURING METHODS
FOR THE PRODUCTION OF
PLUG AND RING THREAD GAGES

SUBMITTED BY DIVISION 12

NATIONAL DEFENSE RESEARCH COMMITTEE

THREAD GAGE MANUFACTURE

A MONOGRAPH

on

METHODS OF MAKING AND INSPECTING

THREAD PLUG AND RING GAGES

Prepared for

The Ordnance Department of the United States Army
under the Auspices of
The National Defense Research Committee

by

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Springfield, Vermont

April, 1943

PREFACE

This monograph presents a detailed discussion and explanation of the methods currently in use for the manufacture of thread gages, both plugs and rings. It has been compiled by the Jones & Lamson Machine Company in partial compliance with the requirements of their Contract OEMsr-497 with the National Defense Research Committee as extended and augmented January 1, 1943. This project was undertaken at the request of the Army Ordnance Department, Liaison Officer, Lt. Col. W. J. Darmody.

500 copies of this Monograph have been printed. The distribution is 40 to the National Defense Research Committee for record, and the balance to the Office of the Chief of Ordnance, Inspection Gage Sub-Office, Philadelphia, Pennsylvania.

FOREWORD

This Monograph has been prepared for the use of tool manufacturers and others who already have a working knowledge of standard precision machine shop practices and who are desirous of learning the special technique involved in the manufacture of thread gages. The text, therefore, deals principally with the operations of threading, lapping and inspecting. Those in need of additional instruction in regard to the machine shop practices involved are referred to in the standard texts on shop practice prepared by the publishers of technical books.

The bibliographies given at the end of each chapter are not intended to be complete; they merely list a few articles for the benefit of those who would like to make a further study of the topic in question. Those interested in a more thorough study of the art are referred to "Screw Threads; a Bibliography of Available Material on Screw Thread Theory, Standards, Production Methods, and Gaging Methods", compiled under the auspices of the National Defense Research Committee.

If the reader does not have direct access to the literature listed, he can obtain photostatic copies of the articles mentioned by writing to almost any large library. The order should preferably be sent on company stationery and the name of the official to whose attention the photostats and the invoices are to be sent should be indicated.

If a complete article is desired, it would be better to state this fact and to give the name of the article, rather than to give only the page numbers listed in the bibliography.

In order to avoid discrimination the names of manufacturers of special gages and equipment have not been given. However, the reader can obtain this information by referring to any of several buyer's directories. Persons unfamiliar with such sources of information may obtain assistance from the gage section of the office of the Chief of Ordnance by application through the office of the local Ordnance District.

A glossary of terms related to the making of thread gages has been inserted in the back of the book. (Appendix II)

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CHAPTER I

SELECTION OF MATERIALS

Checking the steel

In order to avoid lost time in processing the gage, the steel should be checked for chemical analysis before any machine work is done upon it. An analysis of the steel in question will be sent by the mill if requested. It is usually standard practice for gage manufacturers to check this analysis themselves so as to avoid any possible error. The exact analysis is of great assistance to the heat treater in choosing the correct sequence of operations and the right temperatures of both the work and quench.

In addition to the check on chemical analysis, bars or forgings should be checked for hardness when received. This hardness check indicates the machinability of the steel. Machinability in this case refers to surface smoothness obtainable, relative cutting speeds required, and tool life.

When ordering gage steels it is customary to require maximum hardness of Rockwell B-91, and also to specify that the material be normalized and in a spheroidized contition. This hardness and microstructure will assure the best machinability.

A macroetch of each bar received made on a sample disc cut from the end of the bar will indicate ~~the~~ presence of imperfections such as segregations, seams or forging bursts. If any such imperfections exist in the blank, a gage made therefrom will be useless. The macroetch consists of placing the disc, smooth or polished on one side, in a 50-50% solution of hydrochloric acid and water at a temperature between 160° and 175°F. for a time sufficient to bring out any imperfections present. This time is usually between 15 and 30 minutes.

Material

The type of steel to be selected for thread gages depends not only on the size of the gage under consideration, but also whether or not the threads are to be ground after heat treatment. Size determines whether bar stock or forgings are to be used in making gages larger than three inches in diameter because, for this range of sizes, bar stock is not easily procurable, has a greater tendency to crack in heat treatment, and requires more machining.

In either case the range of carbon content should fall between .95 and 1.10%. These steels should be of appropriate

hardenability as determined by the fracture test on 3/4 inch rounds. Tool steel of this carbon range is stable and quite easy to heat treat. Since all of the above class of steels are water (or 9% brine) quenching types, they can be hardened up to Rockwell C-65 with comparative ease. They can easily be ground and have relatively good wear resistant characteristics.

All forgings as well as bar stock should be normalized before machining.

When the gages are not ground after hardening, as in the case of small ring gages, or gages which are turned on a lathe, then the matter of the deformability of the steel becomes a paramount consideration.

Considerable attention should be devoted to procuring tool steel possessing the best non-deforming characteristics. The most satisfactory steels for this purpose are usually either oil quenching or air hardening types. The oil hardening steels usually deform more during hardening than the air hardening type but are returned nearly to size when drawn. Generally speaking, the oil hardening type will be easier to handle.

Heat treaters are urged to follow the recommendations of the manufacturer of the steel they select regarding all phases of heat treatment.

Steels containing chromium, vanadium and tungsten, in addition to carbon and manganese, are quite frequently used for thread gages. These steels are generally of the oil hardening type. Since the quench is less drastic than with water, the hardness readings are not as high as with the water hardening steels.

Before selecting steel for gages, the machining and heat treating facilities of the shop should be thoroughly investigated.

CHAPTER II

PRE-THREADING

Pre-threading refers to forming the threads on the gage blanks before hardening, in order to reduce the time required for finish grinding. There is considerable controversy as to which thread pitches should be pre-threaded and which should be ground from the solid, hardened blank.

In order to clarify this problem, let us consider a #10-32-NF go plug gage. If this gage were to be rough threaded by milling the soft blanks, leaving .012" on the diameter for finish grinding, the time required for milling each piece would be about 1.9 minutes (three machine time). Three machine time means that although one machine can produce only one piece in 5.17 minutes, this figure is multiplied by .37 in order to allow for the fact that one operator can tend to three machines.

The time required to rough grind these threads on a <u>hardened</u> blank (still leaving .012" for finish grinding) would also be about 1.9 minutes.

Therefore, for a shop in which pre-threading is done by the usual process of milling, it will not make much difference whether or not thirty-two pitch threads on gages are pre-threaded. Since the time required for grinding increases roughly in proportion to the thread depth, it is evident that threads coarser than thirty-two should be pre-threaded, and that threads finer than thirty-two pitch should be ground from the solid.

Although it is the practice for most gage making concerns to form the threads on unhardened blanks by milling, grinding has been mentioned on the routing sheets given in this book (Appendix I). This is because it was found by actual trial that a thread grinder could be used to rough-out twenty pitch threads on half inch gage blanks at a rate of one piece every 1.5 minutes (one machine time), whereas thread milling machines could produce the same work at a rate of only one piece every 5.8 minutes (three machine time).

However, thread milling machines have an advantage in that the thread forming and convoluting operations can be performed in one chucking.

Small Ring Gages

Ring gages too small to be milled usually are pre-threaded by turning in a lathe, using a single pointed internal threading tool.

Standards

Pre-cut threads are generally left about .015" above finish size on the pitch diameter. This may be decreased about .003" for fine pitches or increased by the same amount for coarse pitches. The tolerance is -.000, +.003".

It is important to keep a sharp point on the cutting instrument, so that the thread root will be as close to a sharp V as is practical. If the root of the thread is .005" too shallow, the time required for finish grinding will be increased by one third, regardless of how well the thread flanks may have been formed.

Convoluting

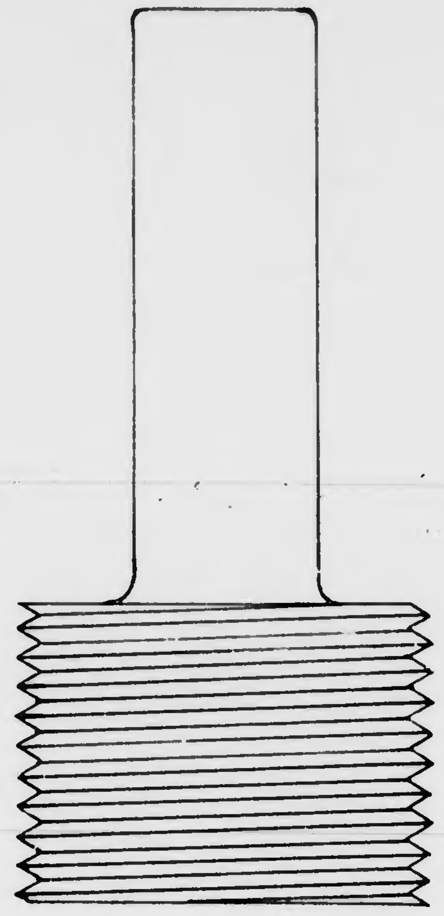
Convoluting is the process of cutting back the threads at the ends of the work so that the threads will start with a thread which has a full form profile, as shown in Figure 1. The convoluted portion of the gage will be similar to a plain cylindrical plug gage, with a diameter a little less than the minor diameter of the finished threads.

Convoluting can be performed after the thread milling operation without removing the work, as follows: replace the pointed cutter with a cutter of the same radius, having a flat on the circumference about as wide as the pitch of the thread; disengage the collet and rotate the work and collet exactly one half turn; re-engage and mill off the threads for one full turn at each end of the piece.

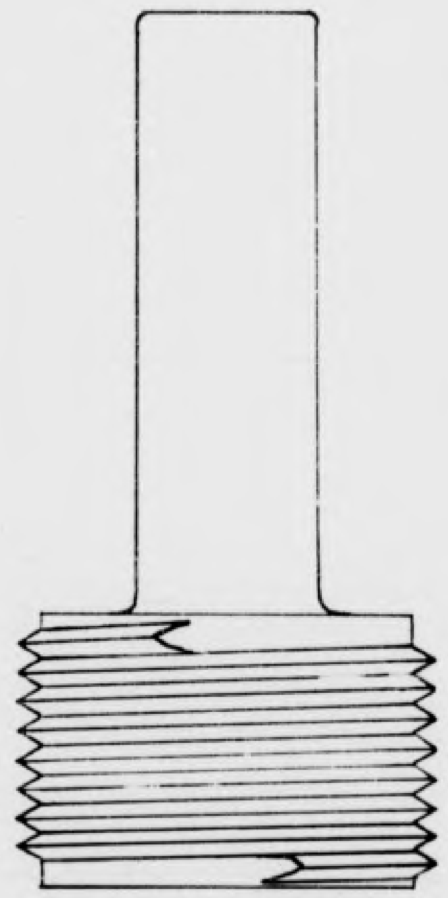
It has been suggested that when pre-threading has been done by grinding, convoluting can be done in the same chucking with the assistance of a small cylindrical grinding attachment, such as is used on lathes.

Special devices can be constructed for convoluting on a surface grinder or on a vertical mill. The necessary principle is merely that the gage must advance with the lead as the thread is turned into the grinding wheel or the milling cutter.

Hardened gages can be convoluted as follows: Take a ring thread gage of the pitch and size in question, clamp it in a drill vice, and stand it upright on the chuck of a surface grinder. Screw the plug to be convoluted through the



UNCONVOLUTED PLUG



CONVOLUTED PLUG

FIG. 1 CONVOLUTING

ring, and adjust the wheel position so that the corner of the wheel will just touch the thread root at the thread start. It will now be possible to convolute this plug, and all others of the same pitch and size, merely by turning them into the wheel.

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CHAPTER III

HEAT TREATMENT

The object of heat treatment is to attain the maximum amount of wear resistance. Hardness and wear factors are, generally speaking, rather closely related. Other factors which affect wear resistance are toughness, absence of surface irregularity, freedom from residual surface strain due to mechanical processing and freedom from grinding burns. The coefficient of friction of the material should be as low as possible in order to minimize the development of scratches through the seizure of the gage with its mating elements.

Federal Specifications require that "thread plug and ring gages shall show a minimum hardness of 60 on Rockwell C scale and show an equivalent hardness by file test on the gaging surfaces." However, it might be wise to harden to about C-65, so that if the surfaces of the gages are softened a bit during grinding, the finished product will still be the minimum required hardness.

Many steels are available which possess very good potential characteristics. To develop these potentialities it is essential that the proper heat treating techniques be employed. Since many desirable characteristics can be secured only through the proper heat treatment of the steels and in no other way, a primary object should be to get the most out of them through heat treatment.

The routing sheet for thread plug gages included in the Appendix illustrates the general heat treating practice for a 1.10% carbon tool steel. If the steel selected tends to crack in the brine quench, an interrupted quench should cure this difficulty. This would be substituted for operation Number 11 and would consist of heating to 1480° F. and quenching in brine for a short time before final quenching for an extended period of time in an oil bath. Many operators hold the piece in the brine until it stops "singing", which can be detected by the slight vibration of the tongs, and then quickly quench in oil.

The temperature range for interrupted quench is between 300° and 700° F. The higher the temperature of the material at the time it is transferred to the oil bath, the greater will be the sacrifice in hardness. A slight increase in initial quenching temperature increases the final hardness to a certain extent.

If modern equipment and trained personnel are lacking, the heat treating should be done by any one of numerous commercial establishments located throughout the country.

CHAPTER IV

THREADING ON A LATHE

The most common use for lathes in gage making shops is in the production of thread ring gages. However, it is also possible to make thread plug gages on a lathe, replacing the grinding operation by rough lapping.

Material

The best material for making thread gages on lathes is a non-deforming oil hardening tool steel. (See Chapter I)

The possibility of scrap will be greatly reduced if the heats are kept separate, and a sample piece or two run for each heat. In this way it is possible to determine in advance the exact allowances which should be made for deformation. The samples should be machined exactly like the other pieces, in order to assure uniform results.

Tools

The point of the threading tool should be kept at least 20% narrower than the specified maximum width at the root of the finished gage, in order to allow for lapping.

In turning thread gages in a lathe, it is possible to use a multiple point threading tool. However, any type of chaser used must be guided by the lead screw; otherwise the thread will not have a sufficiently accurate lead.

Setting the Tools

It is especially important to set the tool by means of a precision tool setting gage, or by means of a dial indicator, in order to make certain that it is perpendicular to the work. Drunken threads will cause considerable time to be wasted in the finishing operations.

To set the tool with an indicator, clamp the indicator to the lathe bed, and place a stop in front of the tailstock in such a way that when the carriage is against the stop, the anvil of the indicator will rest on the cutting end of the tool. Note the reading. Move the carriage away from the stop, turn the tool forward, and bring the carriage back against the stop, with the indicator now at the back end of the tool. When the indicator readings at these two points are the same to within a few ten thousandths, the tool will be in the right position.

Inverted Tools

One particularly good trick in turning threads is to turn the tool upside down and rotate the work backwards, or to place the tool upside down on the far side of the work. This permits chips to fall away from the cutting edge of the tool, and allows the tool to flex slightly, thereby greatly reducing chatter and tearing. The use of inverted tools requires that the cross slide be as tight as possible.

It will be found in most cases that thread plug gages will have to be turned about .0012" oversize on the pitch diameter in order to allow sufficient stock for lapping to a smooth finish. This amount will vary according to the quality of the threads and the exact methods used in the heat treatment. In any event the allowance should not be

more than .0015", because lapping becomes very difficult and expensive beyond this point.

Coarse pitch threads will require somewhat more stock for lapping than fine pitch threads.

MAKING SMALL NON-ADJUSTABLE THREAD RING GAGES

The methods of producing small thread ring gages are considerably different from those used for other thread gages, due to the fact that internal threads less than one inch in diameter cannot be produced by grinding. Even ring gages somewhat larger than one inch are sometimes turned rather than ground because grinding is less efficient for this type of work than for other types. This means that the quality of the product is largely dependent on the skill and the working methods of the individual gage maker. It is hoped that the following suggestions will be helpful, but they should not be considered standard procedure, because there is very little standardization in this field.

Blanks

The blanks should be made in the form shown in Figure 2.

The hole should be drilled about .003" undersize in order to allow for reaming when the blank is chucked for the threading operation.

The flange is useful in reducing the bell mouth effect brought about during lapping. On gages smaller than .510" in diameter, a flange about .100" high can be left on each side. This will serve to cut down the possible amount of twist in lapping. After the threads have been lapped, the

FIG. 2
RING GAUGE BLANK

flange can be ground off even with the sides of the gage, thereby removing the most bell mouthed portion of the threads.

On gages .510" or more in diameter, the regular hubs can be left .100" too wide, and ground to size after lapping.

It might be possible to reduce costs considerably by making some sort of dummy flange which can be clamped onto the gage during lapping.

Mounting the Work

The threads can best be cut on a small, accurate threading lathe. In order to avoid springing, the work should not be held in a chuck, but should be clamped to the face plate, as illustrated in Figure 3. The gage can be centered on the face plate by tightening it in place by guess and then using a dial indicator with a finger contacting attachment. The finger is set on the bottom part of the circumference of the hole.

Next, rotate the face plate and adjust the indicator so that it reads zero at the lowest point. Then rotate to the highest point, loosen the gage, and tap it downward until the indicator reading is half what it formerly was. For example, if the indicator registers sixteen thousandths at the highest point, the work should be lowered until the reading at this point is eight thousandths.

After this, tighten the gage, recheck the centering, and readjust the position, if necessary. The readings should not vary more than one half of a thousandth when the work has been properly centerd.

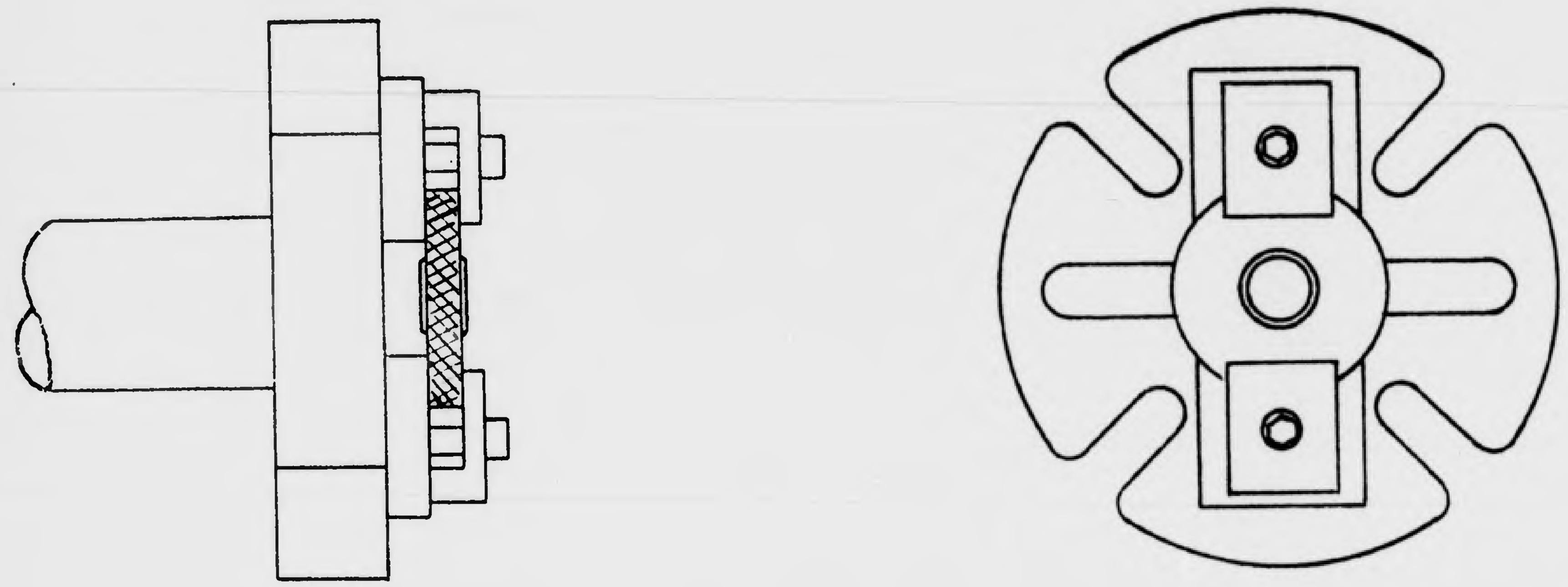

FIG. 3
METHOD OF CLAMPING RING GAUGE

Cutting the Threads

The process of cutting internal gage threads is composed of four steps: reaming, relieving, turning, and hobbing. These are all performed without removing the work or the tool holder, in order to assure concentricity.

These operations generally are performed with a special tool holder, similar to the one shown in Figures 4 and 5. This tool holder is mounted on the cross slide of the lathe at the point where the tool post usually is attached. The tools have tapered shanks and the socket of the holder is also tapered.

However, the use of this type of tool holder requires the expenditure of such a great amount of time that it would seem preferable to use a four square turret tool holder, even though it is not so accurate as the single tool type. Turret tool holding attachments are now available in a form suitable for mounting on an ordinary lathe. They are said to be accurate to the nearest .0001".

The first step in threading is to ream the hole in the gage until it equals the minor diameter of the finished threads. It is impossible, of course, to tell the exact amount to allow for hardening, because of the differences in various steels. However, a good way to start experiments would be to leave the hole at the minimum limit of the minor diameter.

The second step is to turn the relief. The width of the relief should be p/8 for "go"ring gages and p/4 for "not go" ring gages. The depth of the relief should be such that the

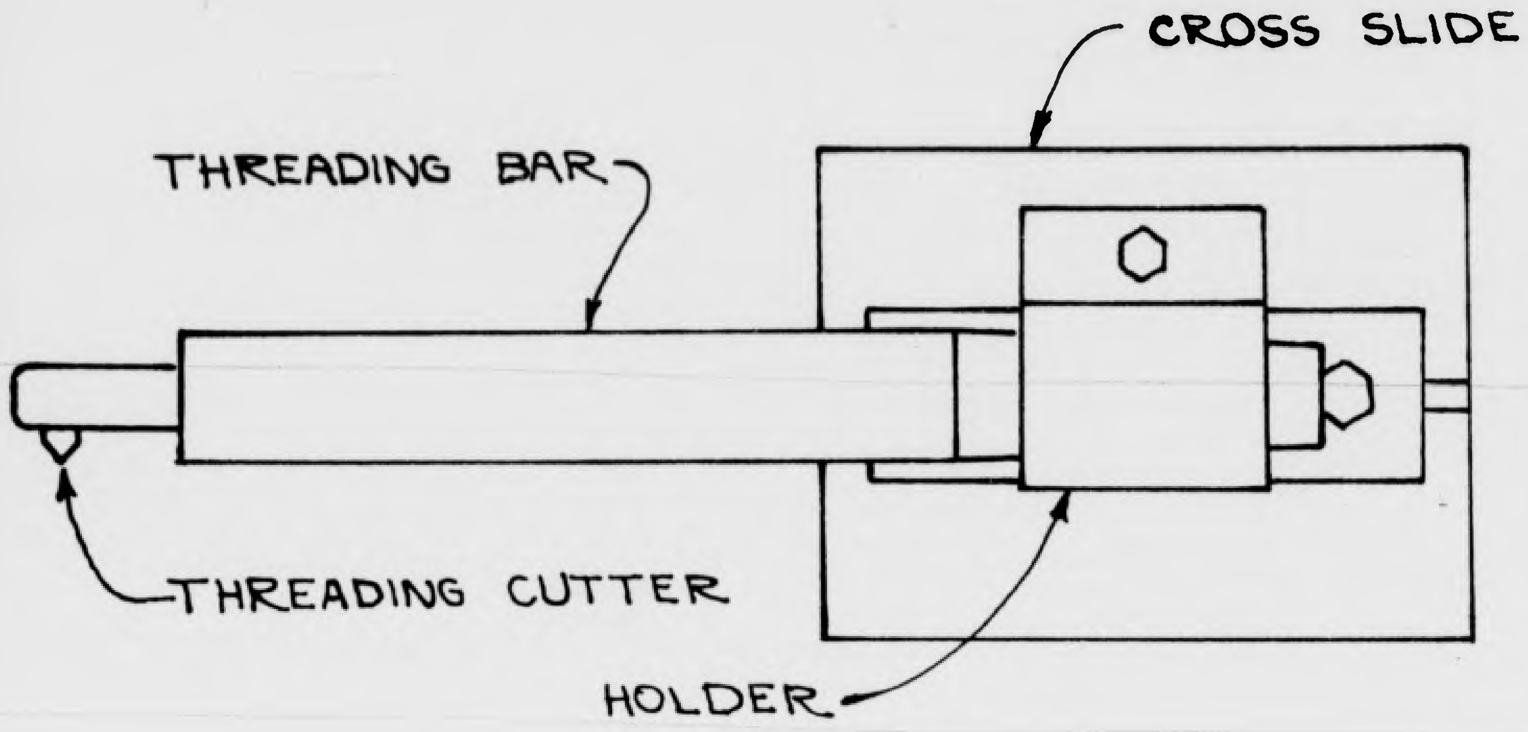

FIG. 4
SET-UP FOR TURNING INTERNAL THREADS

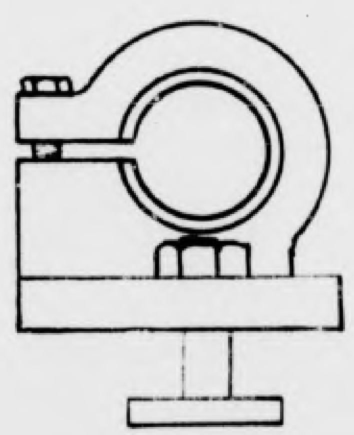

FIG. 5
HOLDER FOR CUTTING INTERNAL THREADS

crests of a sharp "V" external thread will not touch the roots of the gage thread when the two are screwed together. This depth is p/8 x .866 for "go" ring gages and p/4 x .866 for "not go" ring gages.

As an example, consider a 1"-14 NF "go" ring gage. The width of relief would be p/8 = .0714/8 = .0089". The depth of the relief should be .0089" x .866 = .0077". Since the thread depth in this case is 5/8p x .866 = .0386", the total depth cut by the relieving tool should be at least .0077" + .0386" = .0463".

The third step is turning the threads with a single point, internal threading tool. The threads are turned until the pitch diameter is about .004" less than finish size.

Internal threads are generally formed with lighter cuts than external threads, due to the tendency of the threading bar to flex. Flex can also be reduced by setting up with as short an overhang as possible and by using a bar with the largest convenient diameter.

The simplest way of setting the threading tool is with an ordinary threading tool gage, as shown in Figure 6.

The U type of setting gage is more accurate than this, but requires that a center be placed in the headstock temporarily. The actual gaging member comprises a precision ground cylinder with an annular V groove. This is illustrated in Figure 7.

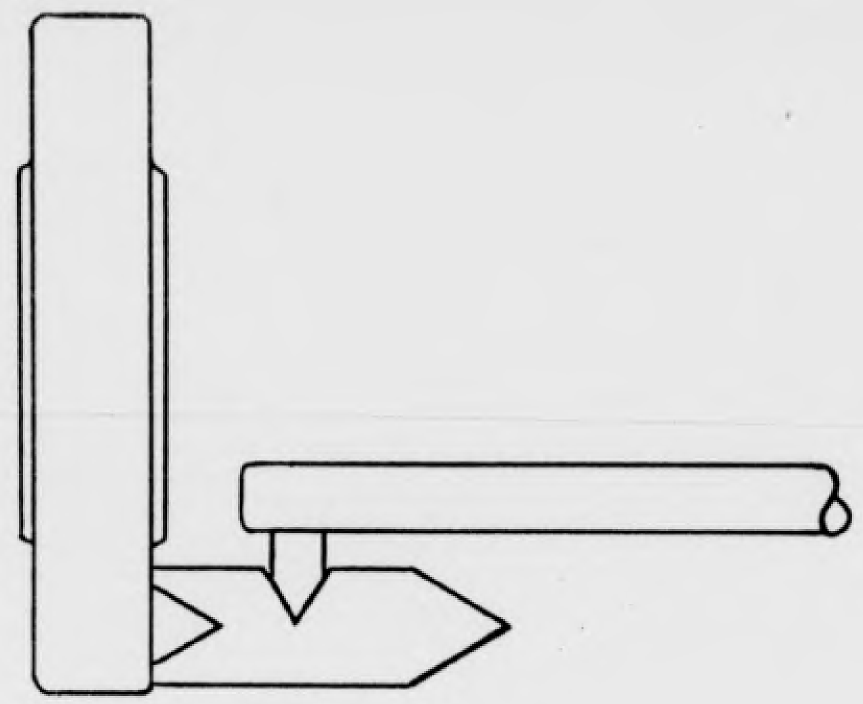

FIG. 6
SETTING AN INTERNAL THREADING TOOL

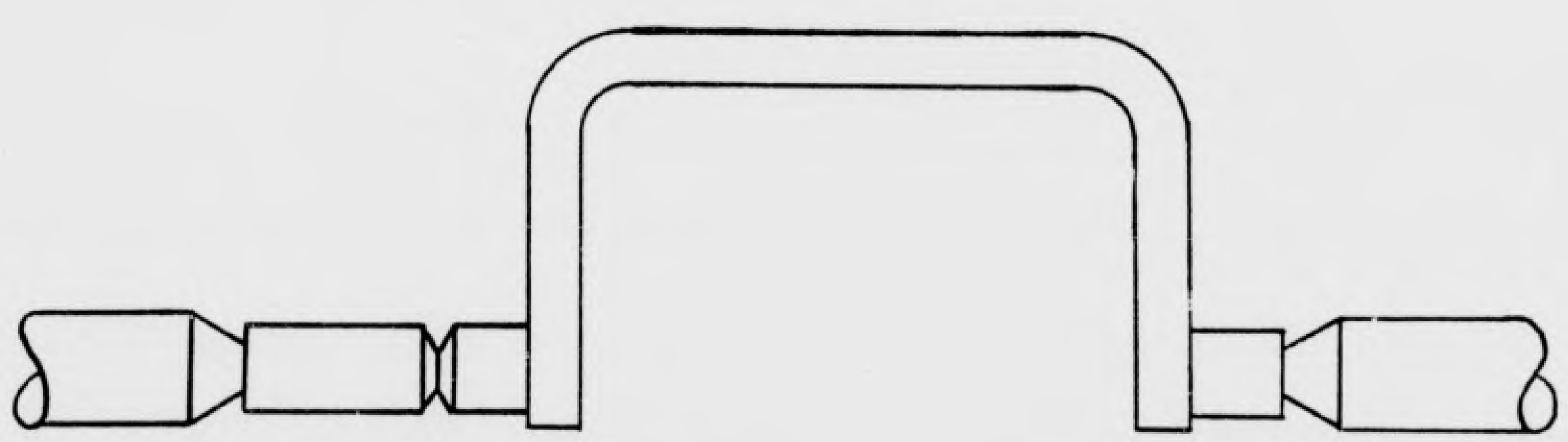

FIG. 7
"U" TYPE SETTING GAUGE

The fourth step is the sizing operation. This can be performed with a short die hob. This tool should have about five threads chamfer, should have no taper or relief, and should have a tolerance of not more than .0003" on the pitch diameter.

A twenty four pitch gage should have from .0004" to .0007" of stock left for lapping after it has been hardened. (This is measured as the amount of undersize as related to the minimum finish pitch diameter). It is impossible to tell in advance how much to allow for lapping when sizing, due to the fact that the size alteration during hardening can vary considerably. The gage may expand, stay about the same, or even shrink a bit depending on the exact type of steel and method of hardening used. However, since the tendency usually is to expand, it would be advisable to hob the first samples so that they are about .0009" less than the minimum pitch diameter.

The standard tap sizes will be too large for this purpose. The only thing to do is to have special hobs made up after experiment has shown exactly how much should be allowed for alteration during heat treatment.

It will not be practical to lap a small ring gage if there is more than .001" of stock to be removed.

The hob should be kept lubricated by means of sperm oil, which is applied with a brush. The hob should be cleaned thoroughly after each piece is made.

The speed of hobbing should be about twenty surface feet per minute.

The hob is turned entirely through the gage. The hob and the gage can then be loosened and removed at the same time, so that it will not be necessary to back the hob out through the gage.

Very Small Ring Gages

Threads on ring gages which are too small to be threaded with an internal threading tool are cut from the solid in one operation by means of a long die hob.

The motion of the hob should be guided by the lead screw of a lathe in a fashion similar to that described above.

In this case also, the hob should not be backed out, but should be removed with the work.

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CHAPTER V

THREAD GRINDING

This chapter is not intended to repeat the detailed instructions to be found in the operator's manuals published by manufacturers of thread grinding machines. Its purpose is merely to explain some of the fundamental principles involved in the thread grinding process, and to describe a few special tricks which may be useful to gage makers.

PRINCIPLES OF SETTING UP

Wheel Selection

The principle to bear in mind in choosing thread grinding wheels is that soft wheels permit rapid removal of stock, but do not retain a sharp point; whereas, hard wheels retain a sharp point well, but cause burn easily. Fine grained wheels hold a sharp point well and provide a smooth finish, while coarse grained wheels have the opposite effect. For this reason, soft, coarse grained wheels are used for coarse pitch threads, and hard, fine grained wheels are used for fine pitch threads.

TABLE I

Recommended Thread Grinding Wheels
For Grinding "Go" Thread Plug Gages

PITCH	GRAIN and HARDNESS (Norton Designation System)
4-10	150-K
10-16	180-L
16-24	220-O
24-36	320-O
36-56	400-M
56-up	500-M

These values apply to vitrified wheels of 38 Alundum, twenty inches in diameter.

For "not go" gages on which relief is going to be ground, the wheel composition can be about 100 grains coarser because of the wider thread root.

It has been found by experiment that wheels for work of large diameter should be somewhat coarser than wheels for work of small diameter.

For shops in which there is not a great quantity of thread grinding done, the 3880 P9, or its equivalent, could be used in place of the variety of wheels listed above. This grade of wheel is a useful all purpose stone for grinding thread plug gages.

In selecting and in using grinding wheels, it is important to remember that the cutting and the wear resisting properties of the wheel depend on the speed at which it is operated. Increasing the wheel speed brings about the same general result as using a harder wheel; decreasing the wheel speed brings about the same general result as using a softer wheel.

Generally, the hardness of a thread grinding wheel should not be any greater than that which is necessary to maintain the desired thread root for a reasonable length of time. This is because the harder the wheel, the more the work must be slowed up in order to avoid burn.

Wheel Mounting and Snagging

The first step in installing a new wheel is to mount the wheel in the machine and to perform the snagging operation. Snagging consists of cutting back the sides of the wheel as shown in Figure 8 so that the grinding surface of the wheel will be only a little wider than the flanks of the thread to be ground.

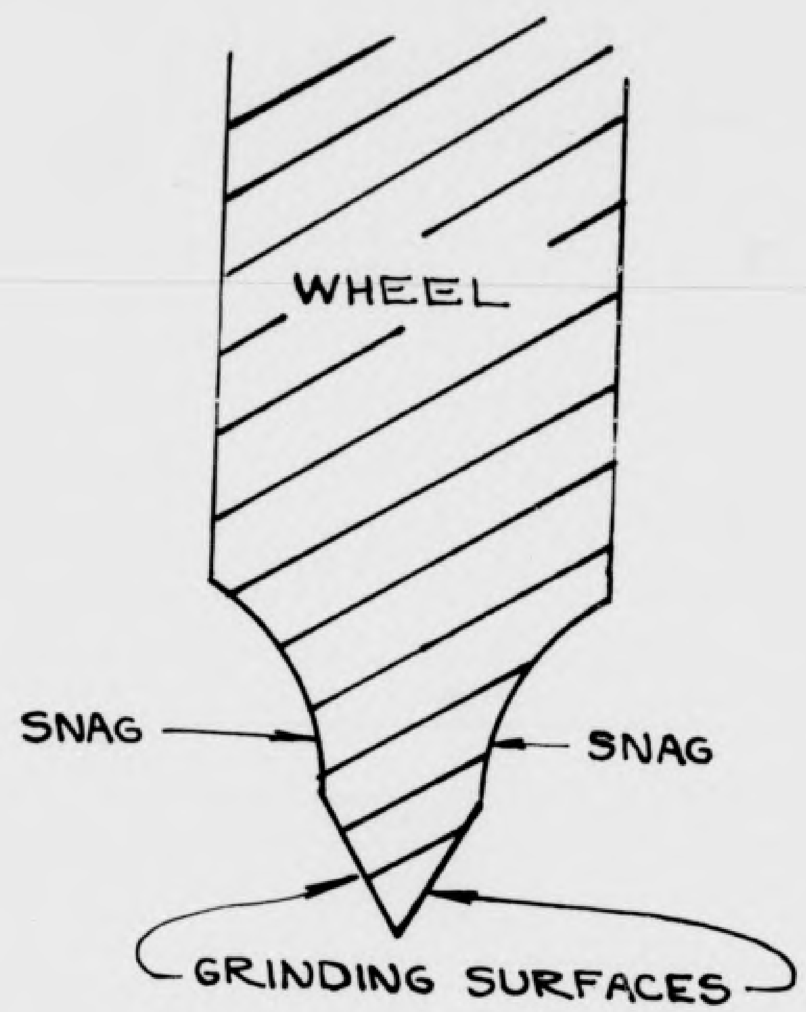

FIG. 8
CROSS SECTION OF THREAD GRINDING WHEEL

The object of snagging is to save diamond wear and to reduce dressing time. The operation can be performed by means of a hand diamond or by means of a wheel thinning device.

The following steps are of particular importance in the snagging operation:

(1) Before mounting the wheel, hold it at the core and tap it with a metal object. If the tapping causes a ringing sound, the wheel probably is satisfactory. If a dull thud is produced, the wheel is cracked, and should be thrown away.

(2) Turn the diamonds back as far as they will go.

(3) Mount the wheel with the manufacturer's markings on the outside, so that if the wheel is ever taken off from the adapter, it can be put back with the same side out. This will cause the point to be located in the same position each time the wheel is remounted, thereby greatly reducing the amount of dressing required.

(4) Before tightening the bolts, tap lightly around the flange to make sure that it is fully settled into position. Make sure that the zero mark on the flange is next to the zero mark on the adapter. Turn each bolt until it is as tight as it can be made by hand. Then go back to the first bolt and again tighten every bolt as much as possible.

(5) Before starting the wheel motor, rotate the wheel by hand to make sure that it is not binding on anything.

(6) Turn on the dressing mechanism so that the wheel speed will be slow.

(7) For protection, keep the wheel guards as low as possible during the operation. Do not stand directly in front of the wheel. The wheel is more apt to break during the snagging operation than at other times.

(8) If the wheel is to be snagged by hand, a piece of carborundum can be used to rough out the form. A hand diamond should then be used to finish the snag. This diamond should be braced on a bar or a piece of work placed between the centers of the machine, in order to reduce vibration. If a snag is not smooth, it will cause chatter.

Wheel Balancing

It is decidedly worth-while to expend considerable time and care in balancing the grinding wheel because a well balanced wheel will not only make it possible to produce work of higher quality, but will also last longer and allow a higher rate of production than a poorly balanced wheel.

Before the wheel is balanced it should be soaked in coolant oil, snagged, and trued. Soaking in oil is necessary because different parts of the wheel will absorb oil in different quantities causing an unequal distribution of weight.

Some concerns soak new wheels in a pan of oil for a few days. However, in most cases it will be sufficient to rotate the wheel four or five times in the machine by hand, with the coolant nozzles trained so as to divert the oil over the wheel. The operator's hands, or a piece of cardboard may be used to deflect the oil stream if necessary.

At this point, it is desirable to grind a piece. If a good finish is obtained, it is obviously unnecessary to add balancing buttons.

If buttons are to be added, this should be done immediately after the trial run. Otherwise, the oil will tend to settle in the bottom of the wheel.

The following instructions should be followed in balancing the wheel:

(1) Set the balancing stand on the floor, or on some other very firm base, so that it will not shift its position in the least when the wheel is placed on it.

(2) Place a ground plate, with perfectly parallel sides on the rails of the stand.

(3) Set a precision level on the plates so that it will be parallel to the imaginary line connecting the adjustment screws A and B, as shown. Adjust the screws A and B until the air bubble is as close as possible to the center of the level. (See Figure 9)

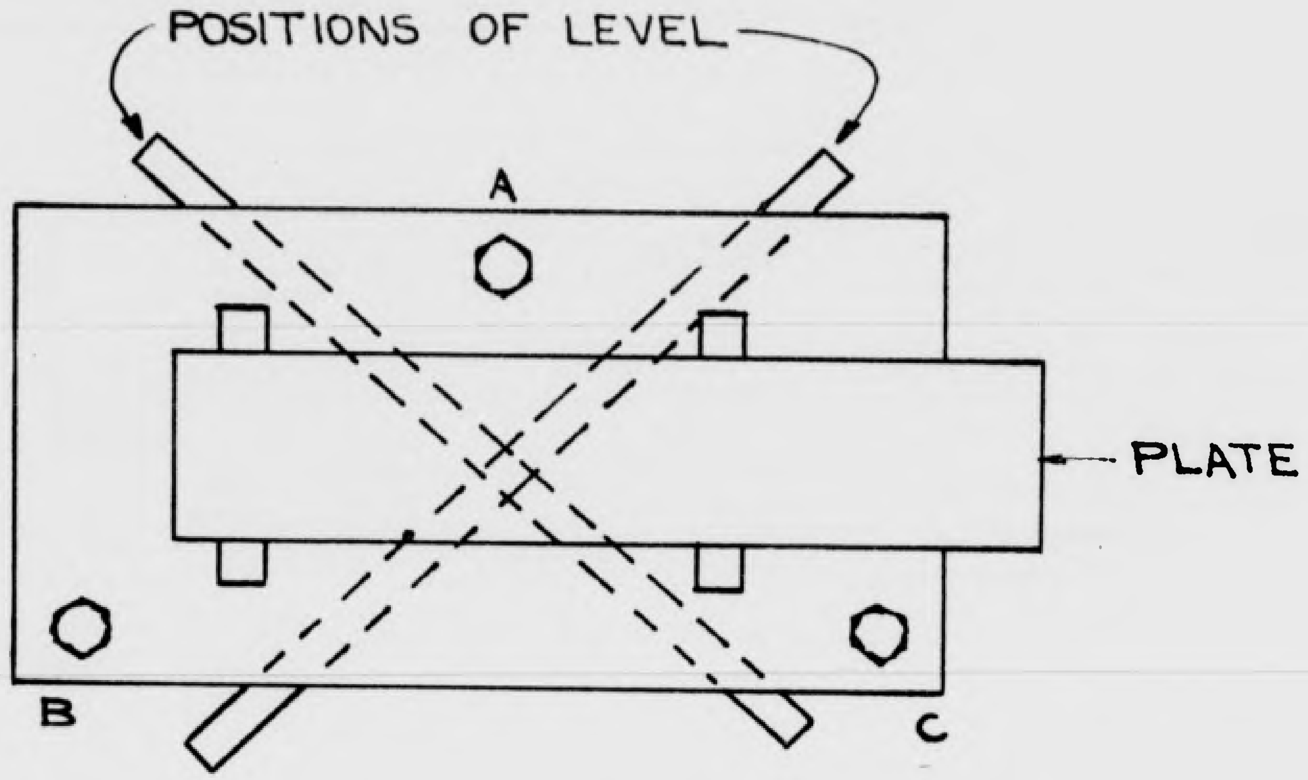

FIG. 9
PLAN VIEW OF STAND

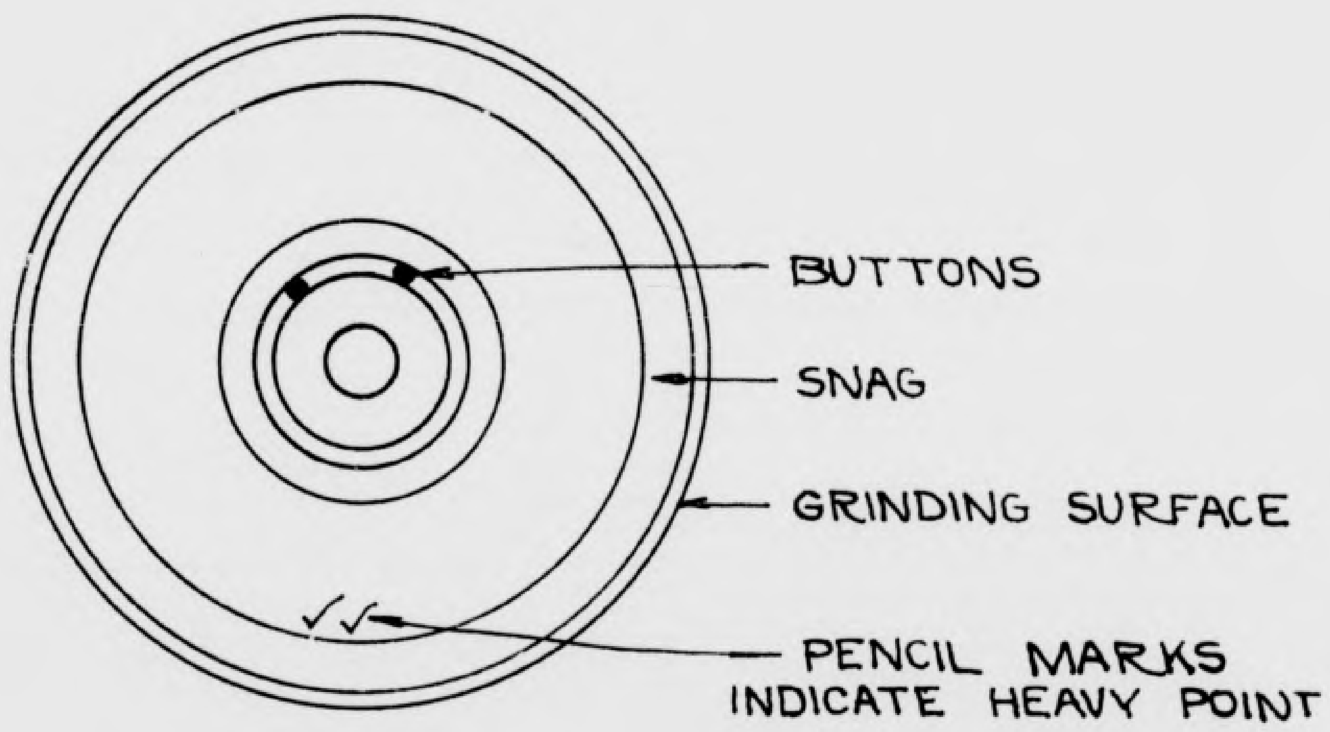

FIG. 10
SIDE ELEVATION VIEW OF WHEEL

(4) Turn the level so that it will be parallel to the imaginary line connecting the adjustment screws A and C. By adjusting the screw C only, bring the air bubble as close as possible to the center of the level.

(5) The stand should now be perfectly level. Check by placing the level in several different positions.

The fundamental idea of this is to level up any two adjusting screws with the level placed so as to be independent of the third. The leveling along the line of the two screws can then be performed very easily, because the level responds directly to the movements of the screws. When the same operation has been performed on a line including the third screw, the entire stand will be level because two lines determine a plane.

(6) Clean the wheel flange and the weight groove carefully.

(7) Place the balancing arbor in the wheel and set it on the stand.

(8) Let the wheel roll until it comes to rest. Mark the lowest point on the wheel with a pencil. This is the heavy side of the wheel.

(9) Turn the wheel about 90° in the direction in which it has been rolling. Release it, thereby allowing it to approach the heavy point from the opposite side.

(10) If the heavy point coincides with the point previously determined, place a balancing button on the

other side of the wheel center, directly opposite the heavy point. If not, continue turning the wheel and allowing it to come to rest until the average location of the heavy point has been quite definitely established.

(11) After one button has been placed, determine the heavy point as before, and continue to add buttons until the wheel is balanced. The wheel will be balanced well enough for general purposes if there are three positions from which the wheel does not roll away.

(12) One or two buttons are all that are required to balance most thread grinding wheels. If it appears that more than three buttons are required, recheck the leveling of the stand and the placement of the first three buttons before adding more.

Truing the wheel over again after it has been partially balanced can also help in cases of this kind, because if the wheel was badly out of balance on the first truing, there may have been enough flex to dress the wheel out of round.

If more than four buttons are required, it will not be possible to obtain satisfactory results under any conditions, and the wheel should be discarded.

(13) For fine adjustments, the effective weight of a fraction of a balancing button can be obtained by placing two buttons equidistant from their normal location opposite the heavy point. The farther apart

the buttons are, the less will be their effective weight. If the buttons are arranged as shown in Figure 10, they will have the effective weight of about $1\frac{1}{2}$ buttons.

Work Speed

The rate of production in thread grinding is limited more by the heat generated in the grinding process than by any other factor. If stock is ground off too rapidly, brown spots will appear on the flanks of the threads, and the work is said to be "burned". Even if this discoloration is removed by light finishing cuts, the threads will not be satisfactory because there will be a soft area under the brown spots. This soft area will wear rapidly when the gage is put to use.

Since all of the heat is generated at the point where the wheel contacts the work, the heat will tend to concentrate in one spot when very slow work speeds are used. Because of this condition, a fast work speed makes it easier to keep the work cool, with subsequent increase in the rate of production.

Fast work speeds and light cuts also produce a much more gradual and balanced stress relief, thereby producing a gage which is stronger and more stable.

The best procedure in setting up for grinding precision threads is to set the wheel feed for a very light cut and then to increase the work speed until the point is reached when further increases would result in excessive chatter and excessive wear of the thread grinding machine. For the standard types of thread grinding machines, a work speed of 240 r.p.m. is about the fastest that can be used with good results.

If chatter develops at only moderately high work speeds, still higher speeds should be tried. Due to natural vibration frequencies of the machine, it is occasionally possible to reduce chatter by increasing the speed.

It is not practical to change from a set up for one work diameter to a set up for a different work diameter merely by computing the surface speed of the work and setting the machine so that the surface speed will be the same for the new job as it was for the completed job.

In the first place, the work speed should be as fast as possible for all types of jobs in order to permit easier dissipation of heat. Adjustments in the rate of stock removal should be made by changing the depth of the cut.

In the second place, the theory of equal surface speeds does not allow for the differences in heat absorbing ability due to differences in the volume of each work piece. A gage two cubic inches in volume will be able to absorb exactly twice as much heat as a gage one cubic inch in volume.

The surface speed of the work varies in proportion to the radius (circumference equals $2\pi r$). The heat absorbing ability of the work, on the other hand, varies in proportion to the square of the radius (volume equals $\pi r^2 l$).

As a specific example, consider the case of a machine set up to grind thread gages $\frac{1}{2}$" in diameter. If this machine were to be changed over to grind gages 1" in diameter, the theory of surface speeds would indicate that the revolutions per minute of the work spindle should be reduced to half their previous number. But as a matter of fact, actual experiment shows that it would not be necessary to reduce the work speed to more than three quarters of the previous value.

Wheel Feed

After the work speed has been set, the wheel feed should be increased until the work shows evidence of burn. This will probably first be noticeable by a darkening of the color of the crests of the thread. When this point has been determined, the mechanism should be set for a feed of about 20% less, so as to make sure that no burning will take place during the actual production process.

Wheel Speed

The next step is to increase the wheel speed up to the point where the chatter becomes excessive or to where the wheel loads up. This is to prolong wheel wear. The faster the wheel speed, the longer the wheel will retain its form, particularly at the point. Increasing the wheel speed also increases the polish imparted to the surface of the work.

In general, wheels for thread gage grinding should have a surface speed of at least 6,250 feet per minute (about 1,200 r.p.m. for a twenty inch wheel). It is possible to balance a wheel well enough to operate at a surface speed of 12,000 feet per minute (about 2,200 r.p.m. for a twenty inch wheel). Care should be taken not to exceed the maximum safe speed specified by the wheel manufacturer.

Dressing Adjustments

On the standard types of thread grinding machines, it is generally desirable to use a medium or slow diamond travel speed for gage making. Faster diamond speeds would produce a duller finish on the work. However, when chatter is caused by smooth diamonds, it can sometimes be eliminated by increasing the diamond speed.

Diamond lines are another type of fault which can originate in the dressing operation. These lines are circular ridges formed on the thread flanks, and are caused by uneven motion of the diamonds as they travel across the wheel. Although this condition is caused by mechanical faults in the dressing mechanism, it can often be reduced or eliminated by changing the diamond travel speed.

In grinding thread gages $1\frac{1}{2}$" in diameter and larger, it is generally the practice to grind the gage down until it is about .002" larger than finish size on the pitch diameter. The diamonds are then fed in from .0003" to .0006" and allowed

to traverse the wheel at least twice. The diamonds are not fed in for the second pass over the wheel; the object of this stroke being merely to smooth the wheel so as to produce a better finish.

In grinding thread gages less than 1" in diameter, the procedure is the same except that it is not necessary to dress the wheel for every piece. Each gage should be checked for sharpness of root, and when the root shows appreciable signs of flattening, the wheel is dressed.

When grinding threads of very fine pitch, it is necessary to dress the wheel by means of several very light strokes of the diamonds, otherwise, the point of the wheel will be broken off. It is also necessary to use very sharp diamonds. Under some circumstances, it may be necessary to perform the dressing operation when there is only .0003" of stock left on the work.

A heavy dressing cut will wear the diamonds more rapidly than several light cuts which remove as much stock in aggregate.

The coolant should always be turned on when the wheel is being dressed.

Belt Adjustments

Care should be taken to see that the belts from the wheel motor and work motor are not tight, because vibration and belt wear both increase in direct proportion to the tightness of the belts. Fortunately, thread gage grinding requires

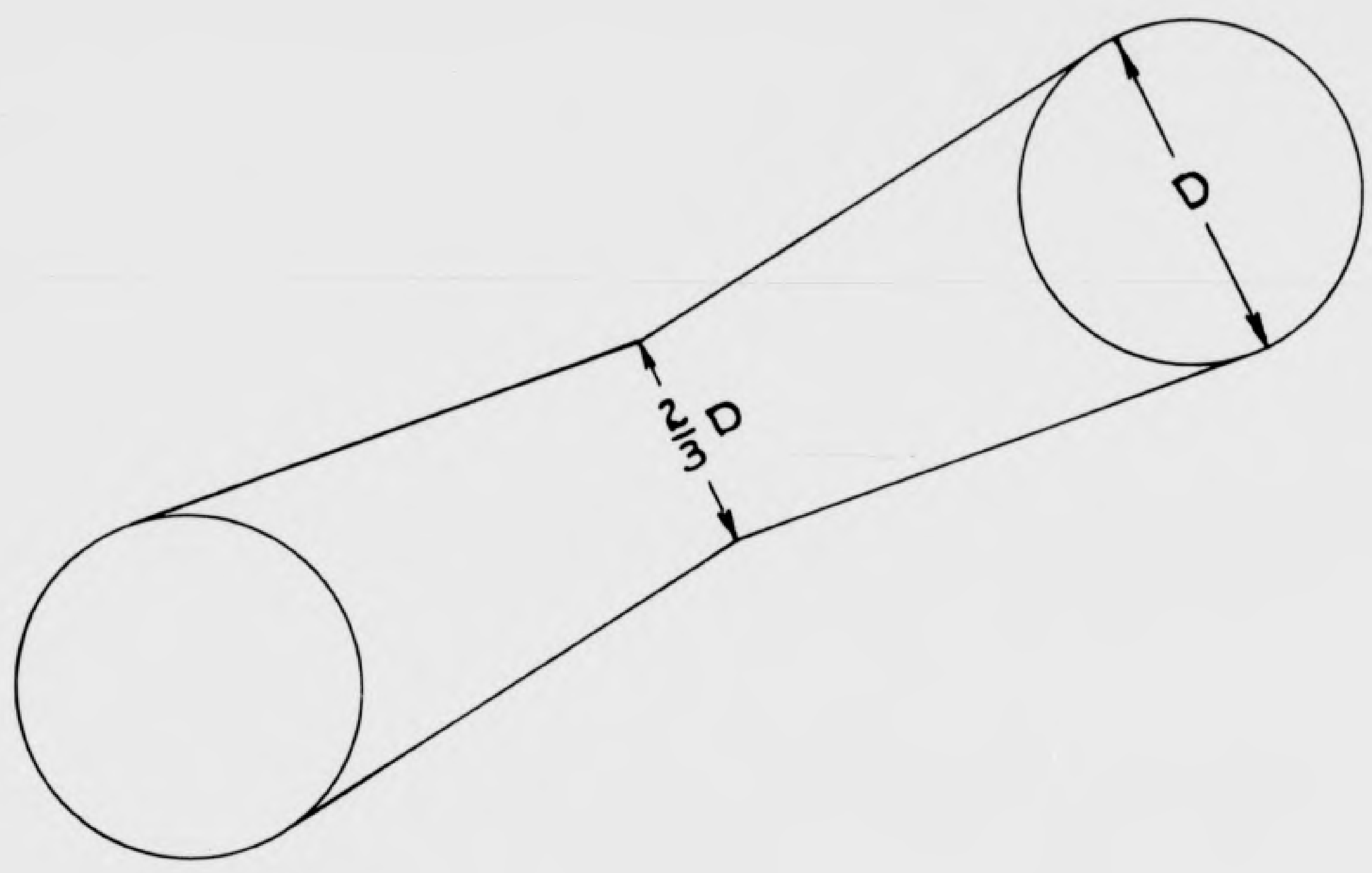

FIG. 11 BELT ADJUSTMENT

very little power, so that having the belts very loose does not cause any particular harm. Although the vibration of the belt itself increase with loosening, experiment shows that the belt is not heavy enough to cause vibrations in the machine. The vibrations which cause chatter are created by the electric motors or by the wheel spindle.

The belt from the wheel motor to the wheel spindle should be so loose that it "squeals" when the machine is started. A good general rule for this belt is to loosen the belt until the distance between opposite side, when compressed with the hand, is from two-thirds to three-quarters of the normal distance. (See Figure 11)

The belt to the wheel should be checked for tightness every two weeks or so, because the oil spray makes it contract.

Coolant

There are several types of coolant oil satisfactory for grinding thread gages. These can be recommended by the thread grinder manufacturer. It pays to change the coolant oil frequently because dirty oil produces a poor finish and makes it possible for the work to burn more easily. When a thread grinder is used constantly, the oil should be changed at least every six weeks.

The operator should take care not to allow any foreign material to fall into the coolant tank. Gages should be washed in gasoline before they are placed in the machine.

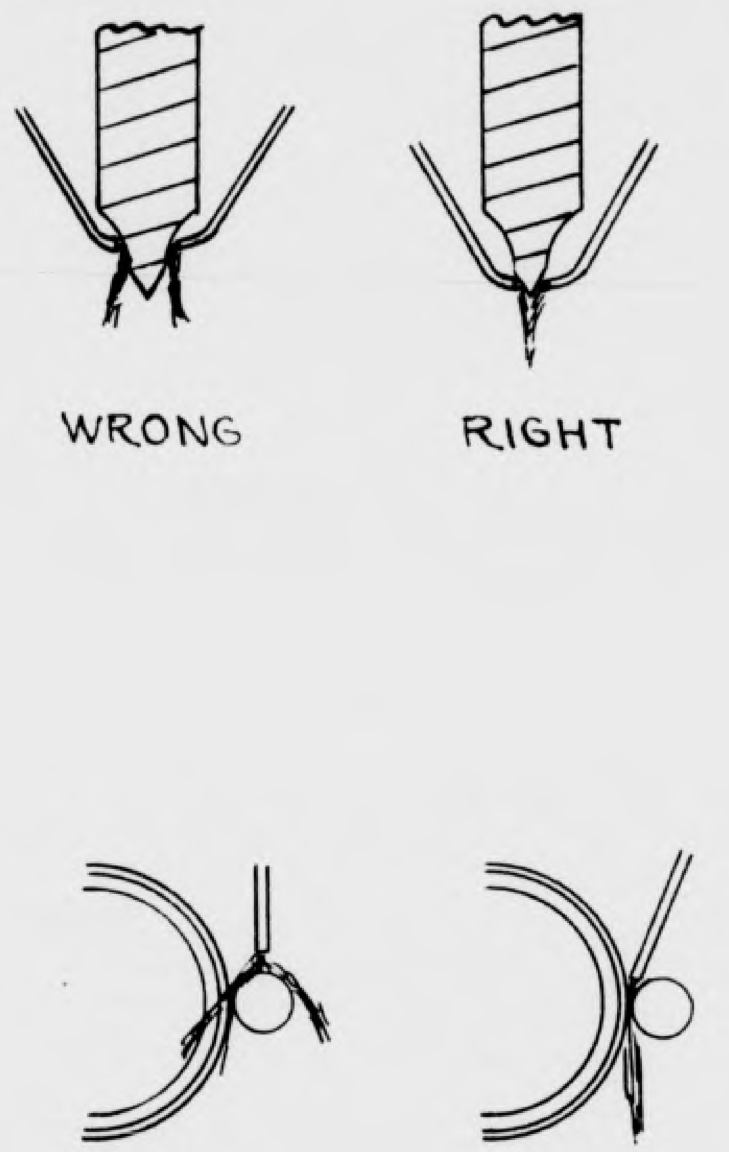

FIG. 12
COOLANT PIPE POSITIONS

Coolant Nozzle Adjustments

Unless the coolant nozzles are adjusted so that the oil is sprayed directly onto the point where the wheel meets the work, the possible rate of production will be greatly decreased. A very common error made by thread grinding operators is to set the nozzles so that the oil stream strikes other than at the grinding point, and appears to flow over it. In fact, however, the oil forms an eddy similar to a vacuum around the grinding point and very little coolant reaches the spot where it is needed most. This condition is shown in the sketches in Figure 12.

Another common error is poor adjustment or actual removal of the left coolant pipe in efforts to avoid interference between the pipe and the dog. This probably accounts for the fact that many thread gages supplied to the Army during the present emergency have worn much more rapidly on one side of the threads than on the other.

If it is impossible to bend the left pipe into a form such that it will spray the work directly without striking the dog, a redesigned dog, which will provide more clearance, should be made up. Under no circumstances should the left pipe be removed entirely.

Work Travel Lead Screw Adjustment

Experiment has shown that a tight lead screw will not only wear much more rapidly than one which is merely snug, but will also generate a much less accurate thread. The proper procedure in setting leaders is to loosen the nut until the screw turns very freely when twisted with the hand. The adjustment on the nut is then tightened until the friction between the nut and the screw is just barely noticeable.

On the tapered housing type of leader, it is advisable to make this adjustment by backing off the front lock ring (that facing the outside of the machine), so that it is entirely loose, tightening the leader nut by means of the back ring only. When the proper fit has been obtained, the mechanism can be locked into position by tightening the front ring.

In producing fine pitch threads on a machine set up for two way grind, it is desirable to have the leader quite snug in order to make the wheel "back track" with accuracy. However, tightening the leader beyond a reasonable snugness will not increase the accuracy of the back track because the threads of the leader will already be bearing on both sides at all times. Under no circumstances should the leader nut be so tight that it is impossible to turn the screw by hand.

Thread Alignment

When grinding pre-threaded work, it is necessary to attach the dog to the work in such a way that the root of the thread will be opposite the point of the grinding wheel when each piece is inserted. The machine is aligned to the first piece of an order, and the other pieces can be "dogged" in exactly the same relationship, by means of a dial indicator type alignment device or by means of a home made fixture. This fixture consists of dummy centers and driving pin to hold the work and dog, and a test tool which is free to slide back and forth in a slot perpendicular to the axis of the work. The work is turned until the test tool fits into the V of the threads, and the dog is then tightened.

It will be much easier to align the threads, both in the fixture and in the machine, if a piece of white paper is placed under the work.

A seven power jeweler's glass will be a help to the operator in setting the dog on the work and in examining the finish of ground surfaces. A jeweler's glass of about two power is helpful in aligning the work in the machine.

As the grinding operation is commenced on each piece, the operator should note whether stock is being ground off both sides of the threads. When the piece is within about six thousandths of finish size, the operator should again look at the gage to make sure that there are no low spots which remain unground and which might possibly be corrected by shifting the alignment.

In instances where gages have previously been rough ground or when gages are reinserted in the machine, the alignment should be rechecked. One way of doing this is to shut off the oil momentarily. If the wheel blackens equally on both sides, the placement of the piece is satisfactory.

Another method is to listen as the wheel starts to cut at each end of the work. Since the wheel touches only the outer side of the thread at the ends, it is easy to determine whether the side in question is being ground.

CORRECTION OF THREAD GRINDER FAULTS

Causes of Inaccuracy in Pitch Diameter

(1) Failure to treat all pieces exactly alike. Once the machine has been set up, the frequency of dressing, the depth of the dressing cut, the work speed, the work feed, the system for bringing the work to size, and all other factors should be exactly the same for every piece if accurate results are to be obtained.

(2) Loose fit in feeding mechanism
Modern thread grinding machines are equipped with means for eliminating backlash and for improving the uniformity of fit in the moving parts of the work feeding mechanism. Nevertheless, it is desirable to finish close tolerance thread gages in the following manner: Set up the machine so that the feed wheel meets the stop when the work is still about .001" larger than the desired size. When the feed reaches the stop, check the size with ball point micrometers or with a hand dial indicator, without removing the work from the machine. Advance the fine feed adjustment about .0003", turn the feed wheel back about a quarter of a turn, and return it to the stop, all before the work travel mechanism has advanced enough to bring the work opposite the wheel. Repeat this operation until the work is of proper size.

(3) Dressing when work is too close to finish size

Generally speaking, the wheel should not be dressed when the work is less than .002" above finish size. In the case of extremely fine pitch threads, however, it may be necessary to dress the wheel when the work is only .0005" above size.

(4) Work too warm

Even under favorable conditions a gage will contract somewhat after it has been removed from the machine and allowed to cool. Under ordinary conditions, an allowance of about .0001" per 1" of diameter must be made when measuring work in the machine. The operator should not make a final check of the gage until after it has cooled.

(5) Ball points not tight

Before starting work, the operator should always make certain that ball points or other gaging members in micrometers and in indicator fixtures are absolutely tight. Looseness, naturally, will cause erroneous size readings.

(6) Ball points worn

Ball points which have been worn out of round, or which have been bent, should be discarded or relapped.

(7) Dirt on the Feed Stop

The feed wheel and its stop should be inspected and cleaned frequently.

(8) Loose Leader

The operator may advance the fine feed adjustment .0001" and find that .0004" or .0006" of stock has been taken off. This is usually caused by failure of the wheel to back track accurately, thereby removing considerable stock from one flank of the thread even though the feed has not been advanced much. The first point to check in instances of this kind is the fit of the work travel lead screw in its nut.

(9) Loose fit between dog and its drive pin

Causes inaccurate back track.

(10) Poor adjustment of back lash compensator

Causes inaccurate back track.

(11) Loose parts in tail stock

(12) Improper operation of dressing mechanism

When the action of the dressing mechanism is irregular, one way of correcting the situation, as far as the operator is concerned, is to dress with two dressing cuts.

Causes of Chatter

(1) Work speed too fast

Chatter generally can be reduced by reducing the work speed. However, in some special instances, due to the natural frequencies of vibration of the machine, chatter may be reduced by increasing the work speed.

(2) Belts too tight

(3) Electric motors out of balance or affected by worn bearings.

In order to ascertain whether vibrations are caused by the motors, the operator should place his hand lightly on the wheel head, on the head stock, and on each of the motors. If the vibrations in the machine correspond in tempo to those of either of the motors, the motor thus indicated will be the source of the trouble.

(4) Poor dressing adjustments

Infrequent dressing, dull diamonds, loose diamonds, and slow diamond travel all tend to cause chatter.

(5) Poor wheel balance

In addition to improper initial balancing, uneven wheel action may be caused by warped sides or by the concentration of oil in one spot. To avoid this, wheels should always be stored in a horizontal position. The operator should not let oil drip onto the wheel when it is not revolving.

At the installation of the wheel, it may sometimes be advantageous to balance the wheel a second time, after the approximately balanced wheel has been trued in the machine.

(6) Wheel speed too high

(7) Snag in wheel too rough

The snagged portion should feel perfectly smooth to the touch when the wheel is revolving.

(8) Nick in wheel

Nicks which are not large enough to throw the wheel badly off balance can be partially corrected by burring the edges of the nick with a file.

(9) Poor coolant

Unclean coolant oil or improperly adjusted coolant pipes can cause chatter because the wheel loads up under these conditions.

(10) Wheel spindle worn, or badly fitted

(11) Wheel too hard

Hard wheels produce more chatter than soft ones as a rule, although this is not necessarily so in every instance.

Causes of Burn

(1) Stock removal too rapid

(2) Work speed too slow

(3) Poor coolant

Unclean coolant oil and improperly adjusted coolant pipes are major causes of burn.

(4) Poor dressing adjustments

Infrequent dressing, dull diamonds, slow diamond travel, and the use of finishing dressing strokes all tend to cause burn because they glaze the wheel. "Finishing dressing strokes" refers to drawing the diamonds across the wheel without feeding them in.

(5) Hard wheel

In order to obtain maximum production, wheels should be as soft as possible. The limiting factor is that the wheel must be hard and fine enough to maintain the desired thread form for a reasonable length of time. Except for extremely large gages, it should not be necessary to dress the wheel more than once for each piece, at the most.

(6) Work material too hard

In order to avoid wasted time in grinding, stock should not be harder than stipulated.

(7) Poor thread alignment

Initial misalignment, or failure of the wheel to back track accurately can cause burn because an excessive amount of stock is removed from one flank of the thread.

(8) Wheel speed too high

High wheel speeds in themselves do not cause burn, in fact, they tend to reduce burn. However, high wheel speeds make it more difficult for the coolant to remove move metal chips and loose emery, causing the wheel to become loaded, with resultant burn.

In short, high wheel speeds do not cause burn until the point is reached where the wheel loads up. Loading can be detected by the discoloration of the grinding surfaces of the wheel.

Causes of Poor Thread Form

(1) Slow wheel speed

The wheel speed should always be as fast as possible. The limiting factors are the amount of chatter and loading.

(2) Poor dressing adjustments

Heavy dressing cuts, dull diamonds, fast diamond travel, and infrequent dressings all seriously impair the production of threads with sharp roots.

(3) Incorrectly set helix

The adjustment for helix angle should be accurate to about half a degree for ordinary threads, and should be as accurate as possible for very fine pitch threads.

(4) Two-way grind

It is often advisable to use one way grind for gages finer than forty pitch. It is also preferable to use one way grind for pitches coarser than ten. If the machine being used cannot be set for automatic one-way grind, the same effect can be obtained by withdrawing the wheel by hand on the return stroke for the last few finishing cuts.

(5) Loose work travel leader

(6) Too much play between the dog and its drive pin

(7) Poor adjustment of backlash compensator

(8) Poor coolant

Causes of Variations in Taper

(1) Loose work travel lead screw

(2) Loose parts in tailstock

(3) Tightening set screws after setting taper adjustment

The set screws in the taper mechanism should be just tight enough to keep the mechanism snug, and should not be changed after the adjustment has been made.

(4) Machine centers worn, or of improper size

(5) Work centers poorly lapped

In particular, it is important to make sure that there is no dirt in the centers. It is preferable to wash gage centers in gasoline and to lubricate the center at the tailstock end before grinding the gage.

(6) Loose work drive belt

One way to check proper adjustment of the work drive belt is to observe the rotational speed of the work as it starts up after being reversed. If the work does not turn up to full speed almost immediately, the work belt should be tightened.

This rule does not apply when the work spindle bearing is warm. In this case, the machine should run at a slower speed.

(7) Binding of dog and drive pin

Where the dog is driven by a pin, there should be just enough play between the two to obviate binding. Where the dog is held by a set screw the post which holds the screw should be free to turn about its pivot.

Causes of High-Low and Out of Round

(1) Tight work travel leader

(2) Wheel out of balance

(3) Bad chatter

(4) Machine centers worn, or of improper size

(5) Work centers poorly lapped

Use of the Tables of Factors for Thread Grinding

These tables will be of value only if they are supplemented by the experience of the operator. For example, a soft wheel is listed under desirable features because it produces a good finish and permits a high production rate. But a hard wheel is also listed under desirable features because it holds its form well. Only actual trial can determine the exact degree of wheel hardness best suited for a given job, and even the value thus determined may vary if the methods of operating the machine are changed. The tables are intended to indicate only the nature of the change in work quality which will be brought about by altering any given set up factor.

T A B L E II

FACTORS WHICH PRODUCE DESIRABLE RESULTS IN THREAD GRINDING

RESULT	Highly Polished Finish	Good Thread Form	High Production Rate
CAUSES	Soft wheel	Hard wheel	Soft wheel
	Fine grained wheel	Fine grained wheel	Coarse grained wheel
	High wheel speed	High wheel speed	High work speed
	Slow diamond travel	Slow diamond travel	Fast diamond travel
	Dull diamonds	Sharp diamonds	Sharp diamonds
	Infrequent dressing	Frequent dressing	Dressing with one pass of diamonds
	Light dressing cuts	Light dressing cuts	Frequent dressing
	Dressing with several finishing passes of diamonds	Dressing with only one finishing pass of diamonds	Soft Stock
	Hard stock	Light work finishing cuts	Clean coolant
	Clean coolant		Good coolant pipe adjustment

T A B L E III

FACTORS WHICH PRODUCE UNDESIRABLE RESULTS IN THREAD GRINDING

RESULT	CHATTER	BURN	POOR THREAD FORM
CAUSES	Fast work speed	Heavy stock removal	Slow wheel speed
	Tightdrive belts	Slow work speed	Soft wheel
	Motors out of balance	Hard wheel	Coarse grained wheel
	Poor wheel balance	Excessive wheel speed	Heavy work finishing cuts
	High wheel speed	Infrequent dressing	Heavy dressing cuts
	Hard wheel	Slow diamond travel	Infrequent dressing
	Rough snag	Dull diamonds	Fast diamond travel
	Nick in wheel	Dressing with several finishing passes of diamonds	Dull diamonds
	Infrequent dressing	Dirty coolant	Dressing with more than one finishing pass of diamonds
	Slow diamond travel	Poor coolant pipe adjustment	Incorrectly set helix
	Dull diamonds	Hard work material	Failure of machine to back track properly
	Loose diamonds	Poor thread alignment	Dirty coolant
	Dressing with several finishing passes of diamonds		Poor coolant pipe adjustment
	Dirty coolant		
	Poor coolant pipe adjustment		
	Bad wheel spindle		

TABLE III

FACTORS WHICH PRODUCE UNDESIRABLE RESULTS IN THREAD GRINDING

RESULT	Inaccurate Size	Taper	Out of Round High-Low
CAUSES	Failure to treat each piece exactly the same	Loose leader	Tight leader
	Backlash in feeding mechanism	Looseness in tail-stock	Wheel out of balance
	Dressing too close to size	Tightening set screws in taper adjustment	Bad chatter
	Warm coolant	Machine centers worn	Machine centers worn
	Ball points loose	Machine centers wrong size	Machine centers wrong size
	Ball points worn	Work centers poorly lapped	Work centers poorly lapped
	Dirt on feed stop	Loose work drive belt	
	Failure to back track accurately		
	Loose tail stock		
	Improper operation of dressing mechanism		

TABLE IV

GRINDING TOLERANCES FOR CLASS X THREAD GAGES FOR CLASSES 1, 2, and 3, THREAD FITS

Threads per Inch	Size Difference from Standard Pitch Diameter		Tolerance in Lead		Tolerance on Half Angle	Allowance at Root
	Go Plug + Go Ring - Inch	Not Go & Set Plug + Not Go Ring - Inch	Work Gage + - Inch	Set Plug + - Inch	-Min.	-Inch
4-8	.0009-.0012	.0005-.0009	.0003	.0002	2	.0007
9-18	.0008-.0011	.0005-.0008	.0002	.00015	4	.0007
20-32	.0007-.0010	.0004-.0007	.0002	.00015	7	.0006
36-44	.0006-.0008	.0004-.0006	.00015	.0001	10	.0005
48-80	.0005-.0007	.0003-.0005	.00015	.0001	15	.0004

Tolerances for Thread Grinders

The pitch diameter limits given in this table are calculated to allow the lapper to remove .0005" before reaching a point .0001" below the upper limit of the finish tolerance for gages from 20 to 32 pitch. This provides .0003" of stock (a depth of .000075" into the metal of the flanks) for removing the grinding marks, and provides .0002" of stock for removing the soft surface layer of metal from which the temper has been drawn by the thread grinding operation. The allowance for removing the grinding marks is more than this for coarse pitch gages and less than this for fine pitch gages because the marks will be deeper on the coarse pitch threads.

Some concerns have used pitch diameter limits about .0002" less than those given in these tables. This practice is satisfactory when it is not necessary to produce gages of the very highest quality.

The allowance for lapping, of course, will vary in accordance with the quality of the ground finish. One of the reasons why gage manufactures use very fine grained thread grinding wheels is that a smooth finish will reduce the cost of lapping.

Some concerns reduce the allowance for lapping to a bare minimum for thread ring gages because of the tendency of ring gages to become bellmouthed during the lapping process.

By "standard" pitch diameter is meant the lower limit of the finish tolerance for go plugs and not go rings, and the upper limit of the finish tolerance for not go plugs, set plugs, and go rings. This standard pitch diameter is the figure which

is stamped on the gage. Considerable confusion will be avoided if the grinders are given their limits with reference to this figure, rather than in the ambiguous terms sometimes used.

The limits of the finish tolerance can be found in the "Tables of Dimensional Limits of Gages for American National Threads", ("Screw Thread Standards for Federal Services - 1942", pp. 56-69).

Angle

The tolerance on the angle of the thread flanks must always be negative; that is, closed at the crest and open at the root so that the included angle will be slightly less than 60°. This is because the lapping compound tends to work out, removing more stock near the crest of the threads than at the root.

Root

The lapping process lowers the thread flanks and, in affect, makes the root shallower and wider. For this reason, thread gages must be ground so that their roots are narrower than the standard width of flat.

In order to compute the maximum permissible width of root, the amounts listed under "Allowance at Root" in the preceding table should be subtracted from the standard width (P/8 for go plug gages, P/4 for not go plug gages). For example, the widest allowable root for a twenty pitch go gage would be $\frac{.050''}{8} - .0006'' =$ .0056".

Relief

American National Standards require that not go thread gages be relieved at the root, the width of the relief being P/4. The groove should be deep enough so that a sharp V test tool will clear the root when pressed against the thread flanks. Another way to judge relief is to place the gage in an optical projector with the shadows of the thread flanks aligned with the sixty degree lines. If the shadow of the root does not fall on the point where the lines meet, the relief is deep enough.

It is not the practice to relieve gages when the pitch is finer than 28, due to the grinding difficulties involved. Accordingly, the roots of all not go gages above 28 pitch should be ground as sharp as possible; they should be at least as sharp as the roots of the corresponding go gages.

In order to perform the relieving operation, it is often the practice to dress the thread grinding wheel to a long thin point by means of a hand diamond. However, if any considerable number of not go gages are to be ground, it will be worth-while to equip the dressing mechanism with ten degree formers, which will dress the wheel to an included angle of twenty degrees.

It is permissible to relieve the roots of go thread gages. However, the savings thus brought about do not appear to justify the expense of the extra operation.

Taper

Ground thread gages should not taper more than .0001" over their entire thread length, and they should always be large at the front end.

Out-of-Round

Thread gages preferably should not be more than .00005" out-of-round on the diameter.

High-Low

High-low is the variation in pitch diameter readings obtained when successive threads on the same straight piece are measured.

High-low should not exceed .00005".

Concentricity

Firms which purchase thread gages sometimes specify a concentricity of .0002" between the thread flanks and the thread crest.

Chatter

The term "chatter" should not be confused with the term "finish". Chatter is the series of ridges running radially from the roots to the crests of the threads, caused largely by vibrations in the machine. Finish is the series of scratches which follow a circular patch along the flanks, concentric with the axis of the threads. These finish marks are made largely by the individual grains in the wheel.

Chatter should be inspected by means of a seven power glass; any chatter coarse enough to be seen with the naked eye is much too rough for gage work. If the ridges of the chatter are very close together, the chatter will probably lap out easily.

If the ridges are far apart, the chatter is serious.

Burn

Burn, or overheating of the work, is indicated by brown spots on the flanks and by darkening of the crests. There should be no burn whatsoever at any time during the grinding operation.

It is important to remember that even if the signs of burn are removed by light finishing cuts, the gage will not be of much value because soft areas will remain under the sections which were formerly discolored. This is because burning can draw the temper of the metal for a depth of several thousandths.

Diamond Lines

Diamond lines are circular ridges, usually few in number, which run along the thread flanks from one end of the gage to the other. These are caused by uneven motion of the diamonds as they dress the wheel.

Diamond lines should be entirely eliminated in gage grinding.

Grinding Checks

Grinding checks are small cracks on the ground surface of the work, generally caused by overheating during the grinding operation.

Checks can be revealed by immersing the work in a solution consisting of 50% hydrochloric acid and 50% water, at a temperature from 160°to 175°F. Fifteen minutes is about the right length of time to leave the work in the liquid.

Checks can be revealed without injuring the work by means of the "Magnaflux" process, equipment for which is available commercially.

Thread gages should not bear any evidence whatsoever of grinding checks.

INTERNAL THREAD GRINDING

For the most part, the grinding principles already given for external grinding apply equally to internal grinding. In addition, the following special points must be taken into consideration:

Wheel Selection

The 150-10-6 (Macklin designation system) has been found to be a very useful all-around wheel for grinding thread ring gages. The 38220-M10 BE and 180 W 9TH (Norton designation system) have also been used with success.

Wheel Speed

Practical wheel speeds generally ru from 12,000 to 15,000 revolutions per minute (about 3,000to 4,000 surface feet per minute for a 1" wheel).

Chucking Up

Work should be centered accurately on the chuck or face plate in order to save grinding time. Generally it is worthwhile to adjust the work so that the eccentricity is not greater than .0005" on the diameter.

It is convenient to set the dial indicator base on the headstock so that it will be possible to place the indicator in its gaging position merely by swinging the support arm.

It is preferable to support the work by means of a face plate, rather than by a chuck. This reduces the tendency of the work to spring.

Thread Alignment

In internal thread grinding it is necessary to align each piece of work separately. However, considerable time will be saved if the work is inserted with the thread start in the same position each time.

The quickest way to match the threads is to throw the gears in the headstock into neutral, and to rotate the spindle until the threads are approximately aligned. The gears are then engaged and the fine adjustment is made by means of the regular alignment adjuster.

It is particularly important to set the backlash compensator with care.

Work Speed

The most troublesome aspect of grinding internal threads is the difficulty in keeping a sharp point on the wheel. In order to alleviate this difficulty, it is generally the practice to use very slow work speeds. Speeds between 5 and 8 revolutions per minute (31 to 50 surface inches per minute for a piece 2" in diameter) are often used.

Work Feed

For the work speeds mentioned above, cuts of from .010" to .016" on the radius are suitable. Threads of twenty pitch or finer can be ground in two passes of the wheel. The first cut should be considerably heavier than the second.

GRINDING THE MAJOR DIAMETER

The major diameter of thread gages is ground in a Cylindrical grinder according to conventional methods.

It is sometimes the practice to perform the second grinding of the major diameter immediately after the finish thread grinding, instead of just after lapping the centers, as stated on the routing sheet. (See Appendix I) Grinding the major diameter after the threads has the advantage of removing stock softened during the thread grinding process, for the crests of the threads are more sensitive to burn than the other portions. However, this method has the disadvantage that sharp crests are inconvenient for thread grinders to handle, and that the time required for grinding the threads is increased in the case of fine pitch threads which are ground from the solid.

Finish grinding the major diameter should be left until after the lapping operation. This is because lapping tends to round the corners of the threads. Although a ground surface will wear more rapidly than a lapped one, this will not matter in this case because the thread crests are subjected to much less wear than the thread flanks.

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CHAPTER VI

THREAD LAPPING

It is very difficult to give exact instructions for lapping threads because slight changes in materials used, or in the desired quality of the finished work, can alter the process radically. The exact materials and methods best suited to any given job can only be determined by experiment. However, the information included in this chapter should serve to shorten the time spent on this experimentation.

Objects of Lapping

1. The most important purpose in lapping thread gages is to give the gaging surface a smooth finish. Other things being equal, the smoother the finish, the longer the gage will wear. Gages with lapped surfaces have been known to wear several times as long as gages of the same material with ground surfaces.

2. The pitch diameter can be controlled much more accurately and dependable by lapping than by other methods of making threads.

3. It is sometimes possible to salvage improperly ground threads by lapping. (Ordinarily, however, it is preferable to grind threads to a form more accurate than that desired on the finished product. This is because adjustments can be made quickly and accurately on a grinding machine, whereas it is a tedious job to correct thread form by lapping.)

4. It is maintained by some that grinding draws the temper of the surface metal even when there is no visible evidence of burning. Therefore, they recommend that thread gages be lapped two or three tenths below the deepest grinding marks in order to remove the soft outer metal. Others state that grinding does not reduce the hardness more than five points on the Rockwell C scale, so that a gage originally hardened to C 65+ for example, would still show a hardness number of C 60+

Unfortunately, there is practically no exact information available on this subject at the present time. However, it probably would be best for firms desiring to maintain the highest quality to lap considerable stock off their gages. Firms desiring to produce only a satisfactory gage, on the other hand, need only to lap off enough stock to remove the grinding marks.

Making Thread Laps

The general principle to bear in mind when selecting material for laps is that a soft lap tends to produce a smooth finish and inaccurate thread form, whereas a hard lap tends to produce a poor finish and accurate form.

Cold rolled steel and a fairly porous grade of cast iron are the two materials most frequently used for thread laps. A beautiful finish will be produced by lead, but the thread form will not be very accurate. Brass and copper are also used occasionally.

The use of hardened steel inserts will make it possible

for a plug or a ring lap to wear many times longer than it otherwise would.

Since the gage will not be any more accurate than the lap which forms it, laps should be made with considerable care. The threads of all laps should be ground, except small ring laps. The latter are generally cut with precision taps, or with long die hobs.

In grinding laps, the tolerances for angle and lead should be at least as small as those for thread gage grinding as given in Table IV. The pitch diameter is not so important since the fit of the lap and work is always adjustable. However, the arcs formed by the threaded surfaces of the lap and the work will not correspond unless the diameter of the lap is fairly close to the standard dimension.

Laps should have diameter tolerances in the same direction as the gages which they are intended to lap. For example, a plug lap, intended for a ring gage, should have a negative tolerance.

The angles for thread laps should have a negative tolerance, making the included angle slightly less than sixty degrees.

The roots of thread laps should be considerably sharper than the crests of the threads which they are to lap.

Ring Thread Laps

Ring laps are generally made of cast iron, or of cold rolled steel. The latter material is preferable because a ring lap, being much shorter than the work, is subject to rapid wear. The cast iron tends to chip off while being

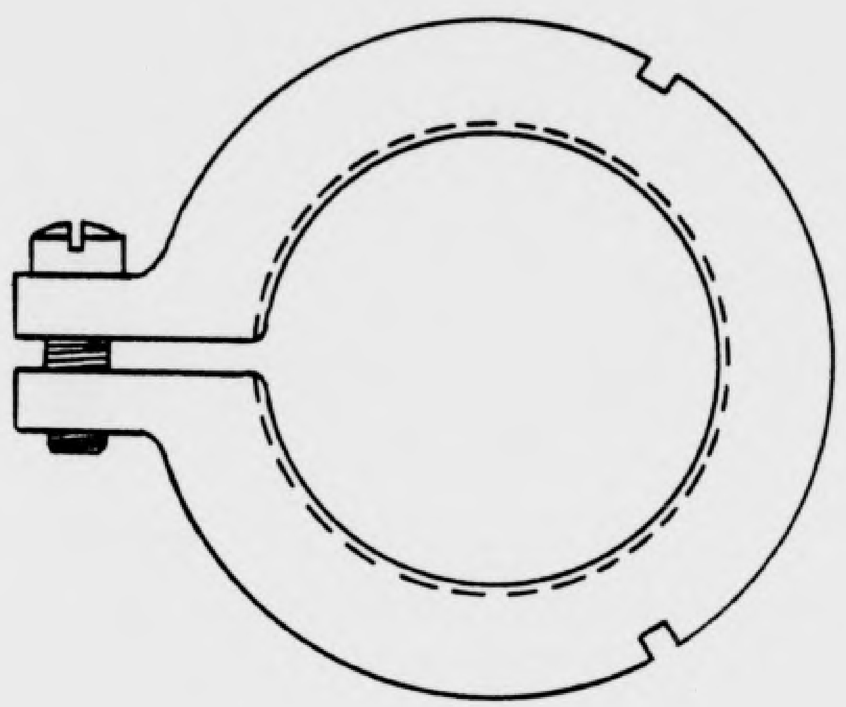

FIG. 13
RING LAP

tapped and used, but the steel does not, at least not to the same degree.

Ring laps should be about three-eighths of an inch thick. This makes it possible to lap one portion of the gage without touching other portions, thereby correcting taper, high ends, or high centers.

The lap shown in Figure 13 is a practical type for use on thread plug gages. This lap may be knurled on the outside, or may be equipped with a detachable handle, in order to make it easier for the operator to hold.

Some concerns make their ring laps in the form of a simple split ring, and use a holder to compress it to the desired size, as shown in Figure 14.

This lap is somewhat less expensive than other types because the holder can be used indefinitely. However, it has a disadvantage in that the arc of the lap does not correspond accurately to the arc of the work. This is partly because the lap must be made oversize, and partly because the holder does not exert equal pressure at all points.

Plug Thread Laps

Plug thread laps are generally made of a high grade cast iron. They are similar to ordinary plug gages in form, except that their length is generally about eight times the thickness of the ring gage on which they are to be used.

Ordinarily, the plug lap need not be adjustable because the fit of the lap and the work can be set by adjusting the ring gage itself. However, a plug lap similar to the one shown in Figure 15 can be used in case a non-adjustable ring gage is to be lapped.

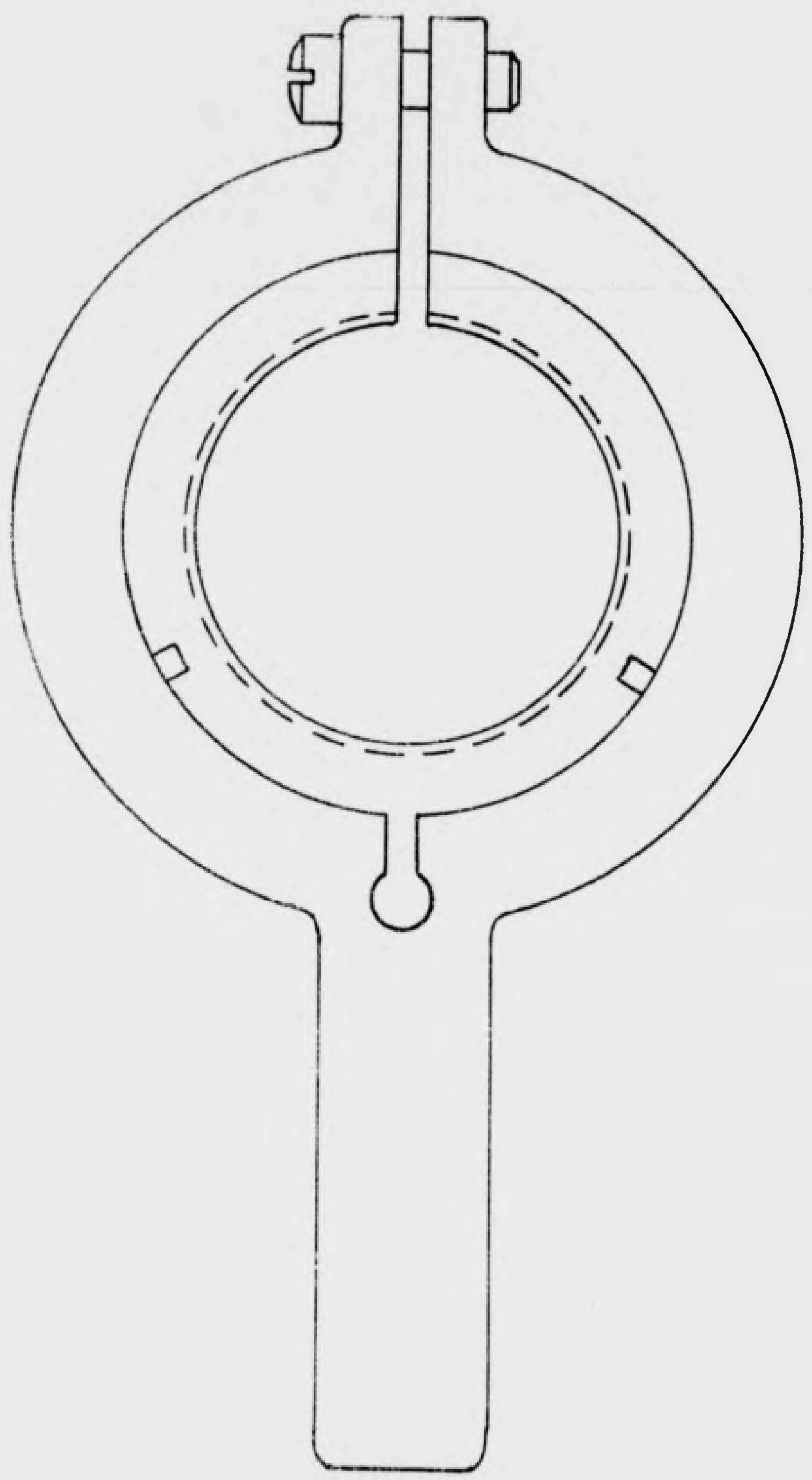

FIG. 14
RING LAP WITH HOLDER

The lap itself resembles a split bushing. The taper should be exactly the same on both the mandrel and the lap, and should not exceed one-quarter of an inch per foot.

The operator increases the diameter of the lap by tapping it lightly so as to drive it farther onto the mandrel.

Corrective Laps

It is customary to use laps with slightly large angles, or slightly small angles, in order to correct errors on the angles of the work. This produces the desired result, but the laps rapidly become useless for this purpose because the lapping process tends to correct the laps as well as the work. A more efficient way of doing this is to use laps which have been drilled in the manner illustrated in Figures 16 and 17.

Root Laps

The ordinary lap bears only on the flanks of the threads. For this reason a root lap, with a thread angle of about fifty five degrees, is sometimes used near the end of the lapping process in order to "touch-up" the thread roots and the bottoms of the thread flanks.

This lap can also be used to deepen the thread roots in case they are too shallow.

Lubricants

It is almost universally the practice to use sperm oil for lapping threads of all types and sizes. Variations in the cutting action and the quality of the finish are obtained

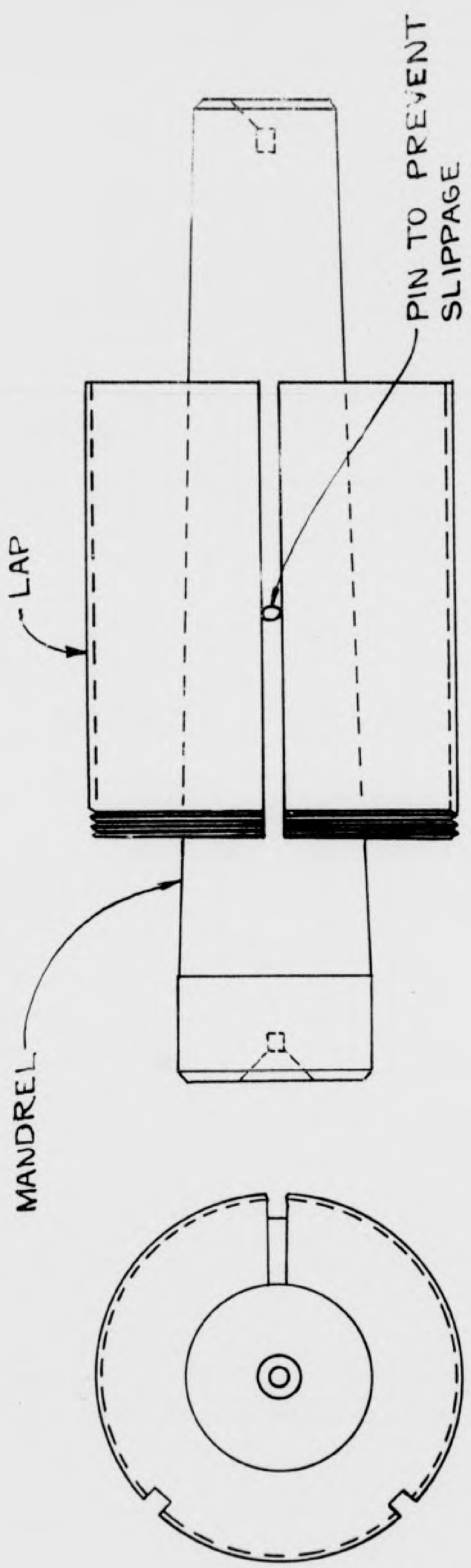

FIG. 15
ADJUSTABLE PLUG LAP

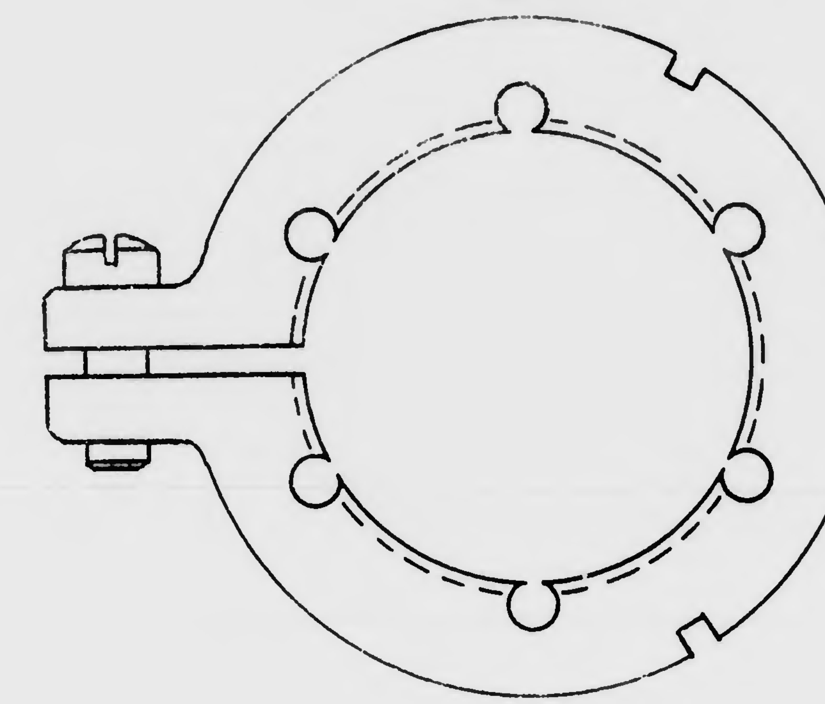

FIG. 16
LAP TO CORRECT LARGE ANGLE

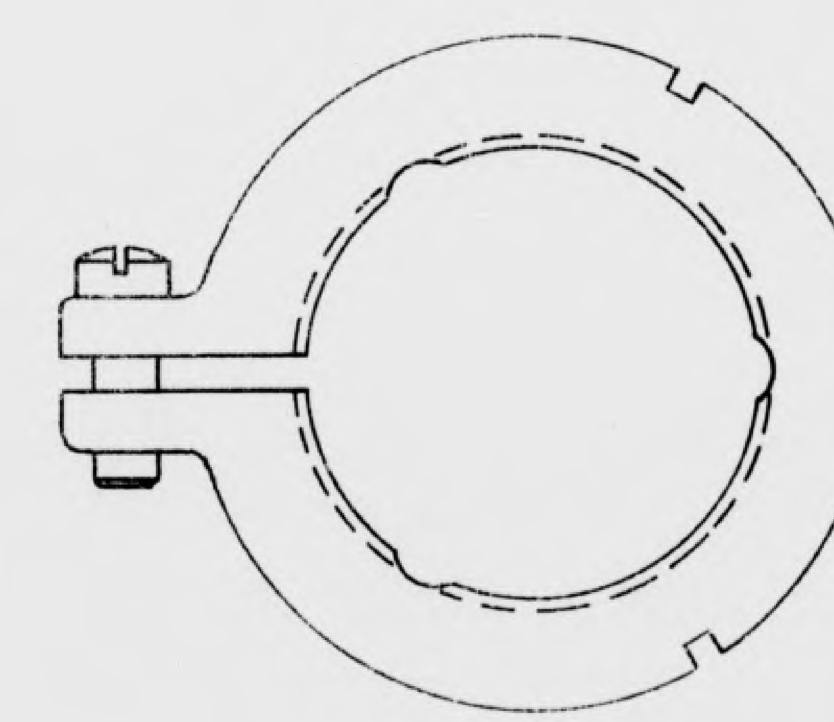

FIG. 17
LAP TO CORRECT SMALL ANGLE

by changing the other factors which influence the lapping process.

However, in case experiments are conducted with different types of oil, it should be remembered that an oil with high viscosity will produce slow cutting action and a smooth finish, whereas a thin oil will produce fast cutting and a comparatively rough finish. This is because the work and the lap do not touch each other directly when in motion; they ride on the film of oil which lies between them. If this oil film is thick, only the outermost points of the abrasive grains will touch the work, producing narrow shallow scratches. On the other hand, if the oil film is very thin, a very large portion of each abrasive grain will contact the work, and heavy scratches will be produced.

In applying this rule, or other rules related to lapping, it is important to remember that these rules indicate tendencies only, and that they are not necessarily valid unless all other factors in the lapping process are held constant.

As an example of this point, consider the lapping of gage blocks, an article on which it is essential to obtain finish of the very highest quality. Despite the rule relating to the viscosity of lubricants, kerosene, or some other very thin liquid is used in this process. This is because the emery used is so extremely fine that no cutting action at all will be produced if a thick oil is used.

Abrasives

There is nothing of particular importance to bear in mind when selecting abrasives except the obvious rule that large grained abrasives produce a comparatively rough finish and fast cutting action, whereas fine grained abrasives produce a smooth finish and slow cutting action.

For rough lapping threads, American Optical 302, Carborundum W440 Medium, and Washington Mills 10X, are satisfactory grades.

For finish lapping threads, American Optical 305, Carborundum W440 Extra Fine, and Washington Mills 12X are satisfactory grades.

Mixing Abrasives

To mix the abrasive with oil, lappers generally take a container about the size of a small cup and fill it about one-third full of emery. They then add some oil and stir, continuing until the container is full.

Some operators let their mixture settle a bit before use. They then dip their sticks down deep when they want a coarse mixture, and dip their sticks just under the surface when they want a fine mixture. However, it probably is easier for the average operator to obtain consistent results if the emery is stirred frequently.

At any rate, it is important to stir the mixture each time some is withdrawn unless selective method mentioned above is being used.

Methods of Charging Thread Laps

The abrasive compound always works outward during the process of lapping threads. In order to prevent this tendency from causing the angle of the work to be too large, it is preferable to add abrasive by placing it on the thread flanks near the roots of a plug, or near the crests of a ring.

When lapping thread plug gages, it is most convenient, and generally quite satisfactory, to add the emery by painting it onto the gage itself. The gage is rotated and a thin stick or wire covered with lapping mixture is pressed in the root of the thread until it has traversed the full length of the gage. The stick should be twisted slightly with respect to the plug axis, so that the abrasive will be spread over approximately the lower third of the thread flanks.

When one portion of the gage is large, this can be corrected in part by painting emery only on this portion.

In lapping ring gages, the emery can be painted onto the plug lap in a manner similar to that already described. If the gage is tapered, correction can be made by painting one section of the plug lap and screwing the gage onto this section small end first.

It is important not to add too much emery. Excess abrasive will merely churn around loose between the lap and the gage, interfering with the cutting action and spoiling the finish. The operator can quickly learn what amount of abrasive is most efficient by trying to lap with various amounts.

Rotating Devices

In order to provide the motion for thread lapping, the lapper should be furnished with a rotating device equipped with collets suitable for holding plug gages and plug laps.

This device should be driven through a straight belt and crossed belt coupled by a friction clutch, or through some other means which permit easy and frequent reversing. It will be more convenient for the operator if the reversing mechanism is controlled by a lever which fits over the knee, or by a foot pedal.

The speed of rotation for thread lapping generally ranges from about sixty to about one hundred and twenty revolutions per minute.

Fast speeds produce slow cutting action and smooth finish, while slow speeds produce fast cutting action and comparatively rough finish. This is because fast speeds build up a thicker oil film, which blankets the grains of abrasive as previously described.

Adjusting the Lap and Adding Abrasives

After the lap has been charged with emery, it should be adjusted to give considerable clearance between itself and the work, and should then be screwed onto the work. The rotating device remains stationary during this step.

Next, the lap is tightened until a slight drag is felt. The greater the pressure of the lap on the work, the faster will be the cutting action and the rougher will be the finish.

As the work wears down, the lap can be tightened and lapping mixture can be added.

The lap can be tightened whenever it feels extremely loose. The best way to determine when abrasive should be

84. added is to lap without adding abrasive, measuring the work frequently. When the point is reached where further lapping does not remove an appreciable amount of stock, the amount of stock removed and length of time elapsed should be noted. After this, abrasive can be added whenever the stock removal or the time lapse is a little less than that which was noted in the above experiment.

Under no circumstances should the lap be so tight that the gage heats up appreciably. This makes it very difficult to measure accurately. Even under normal conditions it is sometimes advisable to make a slight allowance for heat.

Too great a working pressure, or too much abrasive, can cause more harm than not enough.

Guiding the Lap

The operator should take care to keep the ring perpendicular to the rotating plug. This is particularly true of ring gages, which can easily be made bell mouthed by being twisted during the lapping operation.

The inexperienced operator should examine his work when the grinding marks have been about half removed. The smooth portions of the gage will reveal whether too much pressure has been exerted to the right or to the left.

The lap should be reversed (removed, and turned end for end) occasionally in order to compensate for drunkeness in the thread angle and for other errors.

Timing

Lappers generally judge the amount of stock removed by timing. For example, let us suppose that a lapper discovers by trial that for a certain job, with certain working conditions, one ten-thousandth of an inch of stock will be removed from the pitch diameter in two minutes of lapping. Then if he wishes to remove three ten-thousandths on the P. D., he will lap for a little less than six minutes, check the size, and then make a few more lapping passes to bring the work to the desired diameter.

Finish Lapping

Thread lapping is sometimes divided into two operations: rough lapping and finish lapping. This division is not necessary, but it does generally bring about an improvement in the quality of the finished gage. In addition, the rough lapping operation provides a good means for breaking in inexperienced men.

The point at which finish lapping should begin is arbitrary. One system for a go plug gage with a tolerance of .0003" is as follows: Rough lap until the pitch diameter equals the basic +.0004". Finish lap until the pitch diameter equals the basic +.0002" This leaves the finish lapper .0002" to take off, and .0002" extra to work with in case the gage is returned to him because of a scratch or other minor imperfection.

It is considered good practice ordinarily to leave the gage at +.0002" instead of at the upper limit of +.0003" partly because a large gage can reject satisfactory work, and partly because the customer's methods of measuring gages may differ from the gagemaker's thereby introducing doubt as to whether or not a gage near the upper limit is actually within the tolerance limits.

Laps which have been used for rough lapping should not be used for finish lapping because it is impossible to remove all of the coarse abrasive from the metal.

As a preliminary step to finish lapping, it is often advantageous to "touch up" the root and the bottom of the flanks with a fifty-five degree lap.

In preparing for a finish lapping job it is important to determine how long a charge of lapping mixture will cut before it loses its power. The method employed is similar to that described for rough lapping.

With this knowledge in mind, if the operator plans his work so as to avoid adding fresh abrasive when the work is near size, the finish will be superior and there will not be so much likelihood of lapping the work undersize.

The system described above brings about such a good finish because of the fact that the abrasive particles are continuously being fractured into smaller and smaller pieces during the lapping process. Furthermore, their edges are probably rounded to a certain extent. When the particles are about to reach the point where they lose their cutting power, the scratches which they make are very small, hence the smooth finish.

Another factor which affects the quality of the finish is

the frequency with which the direction of the rotation is reversed. Metal which has been scraped off tends to pile up in front of the individual abrasive grains somewhat like snow piles up in front of a plow. As this metal accumulates, it impairs the quality of the finish because it causes a smearing action instead of an efficient cutting action.

One way to correct this situation is to place the plug in a vise and to perform the finish lapping operation entirely by hand, using short jerky strokes about one-quarter of an inch in length. The elimination of smear metal is probably the reason that old time gagemakers are able to get a better finish by hand lapping than can be obtained by means of a mechanical rotating device.

A more convenient means for accomplishing the same result is to insert the plug in an oscillating device which will impart a very rapid reciprocating motion, with a short stroke. The ring can be screwed slowly along the plug by hand. This idea has not found general acceptance among gage-making concerns, possibly because it is somewhat slower than the plain rotating motion.

Finishing the Major Diameter

The thread crests should not be lapped at all. Instead, they should be finish ground after the lapping operation. This is done so that the tops of the thread flanks will have sharp corners.

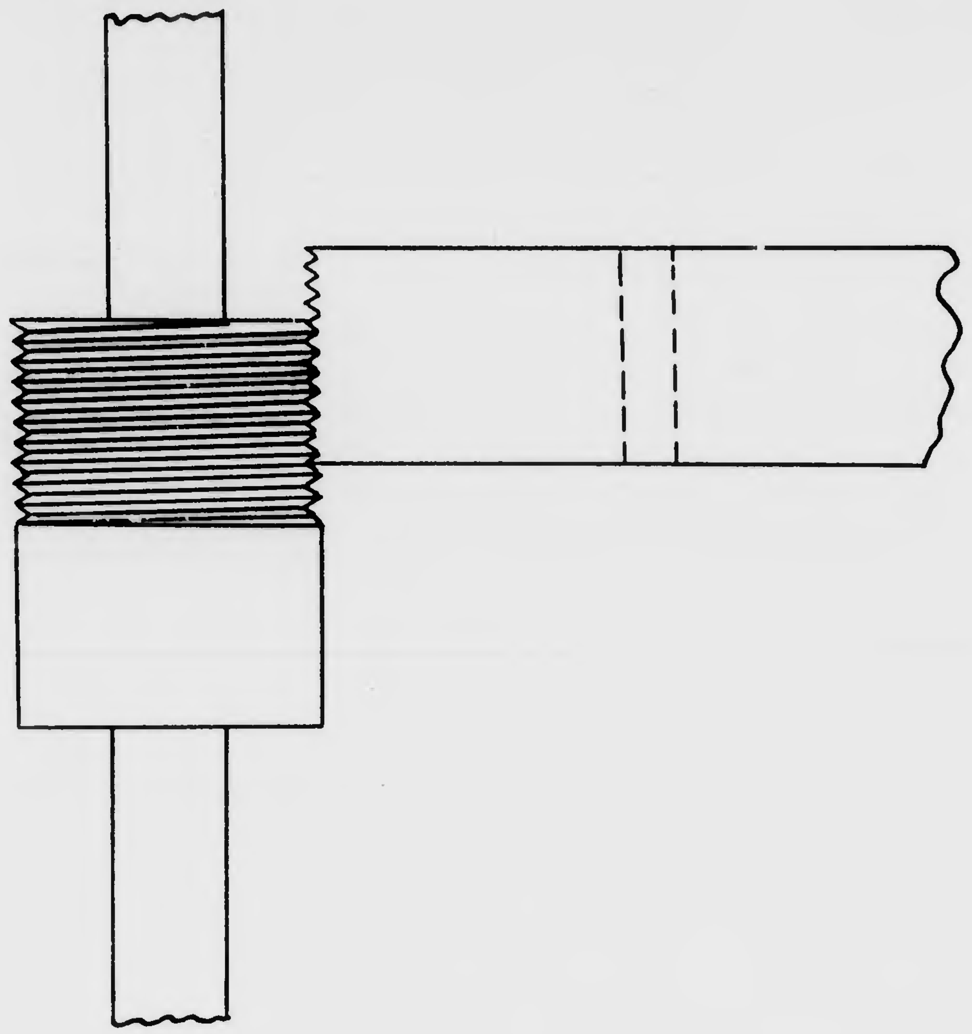

FIG. 18
POLISHING - PLAN VIEW

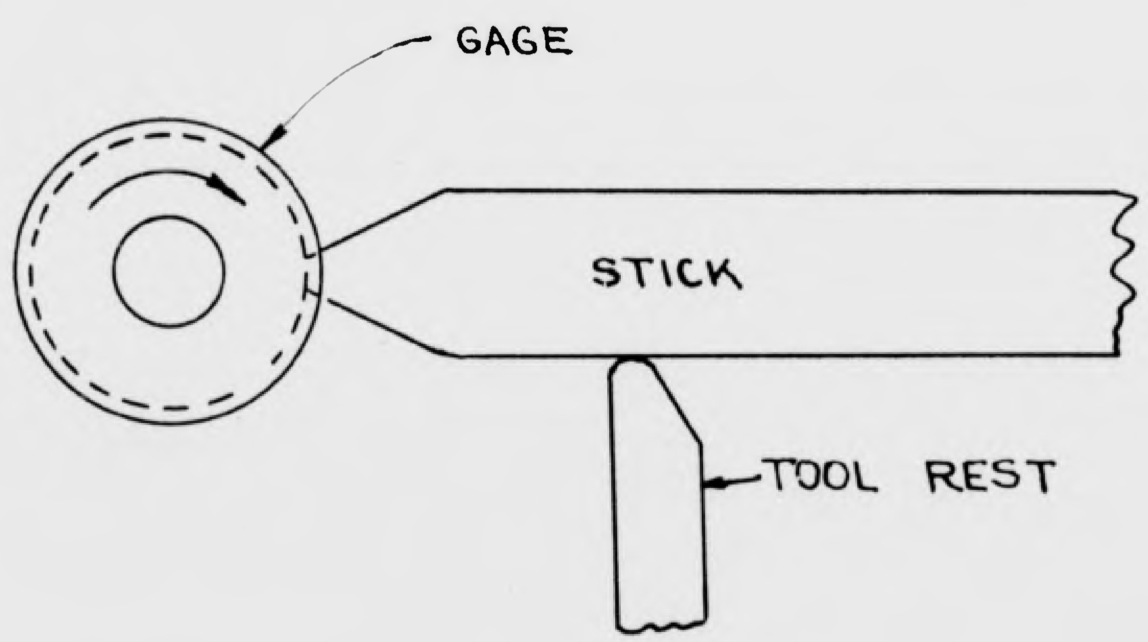

FIG. 19
POLISHING - END VIEW

After the finish grind, it is possible to touch-up the major diameter with a plain cylindrical lap without rounding the corners appreciably. However, this operation is not of much value because there is very little wear on the major diameter.

Polishing

Gages which do not need to be very accurate can be given a smooth finish by an operation sometimes called polishing. This consists of dipping a thin, flat stick of soft wood into a mixture of sperm oil and abrasive, and forcing it against the rotating gage, as shown in Figures 18 and 19.

The operation should be discontinued as soon as the grinding marks have been removed from the pitch diameter, the exact amount of stock removal depending on the quality of the ground finish. The abrasive used should be the same as that employed in rough thread lapping.

Lead errors will be reduced if the stick is inverted frequently.

The thread profile can be formed on the stick by rotating the gage and thrusting the stick against it. Abrasive should not be added until after the threads have been cut. This step will be easier if the front of the stick is whittled to a wedge about 1/32" thick at the point.

In case of coarse pitch threads, it may be necessary to cut the thread profile in the stick by means of a triangular file. When this is done, the pitch of the thread can be marked on the stick by contact with the thread crests of the gage, in order to provide a guide for the filing.

The advantages of polishing are that it is a very rapid, inexpensive process, and that it produces a very smooth, good looking finish. The disadvantages are that it does not correct out-of-round or taper to any great extent. It is also possible that polished gages are somewhat softer than lapped gages, due to the fact that polishing may not remove all of the surface layer of metal which was softened during the grinding operation.

The decision as to whether to lap or to polish ordinary thread gages depends upon the quality desired in the finished gage. All that can be said here is that at present, the manufacturers who make gages of the highest quality prefer lapping to polishing.

However, it appears to be necessary to finish all gages of extremely fine pitch by the polishing method, regardless of the quality desired. This is due to the difficulty of making fine pitch laps, and of lapping fine pitch threads without distorting the form unduly.

Standards of Lapping

The tolerances for lapping are the same as the tolerances for finished gages as given on pages 52-69 of "Screw Thread Standards for Federal Services, 1942".

It is considered good gage making practice to restrict taper to .00003" for the entire thread length, and to limit out-of-round to .00003" on the diameter, although there are no official standards for these elements. Taper should al-

ways be minus (large in front), for taper lock plug gages. This is partly because such gages wear more in front than in back, and partly because it is not desirable for the operator to turn a gage in quite a ways and jam it, before he discovers that the part being inspected is too small.

Cracks, pit marks, heavy scratches, or other imperfections should not be present on the gaging surface. This is because such cavities collect chips and pieces of dirt, which injure both the gage and piece being inspected.

Judging Lapped Finishes

It is often assumed that a bright, shiny finish is the best. This is not necessarily so, because a shiny effect indicates the presence of a great number of comparatively large scratches, which reflect the light in all directions. This condition is shown in Figure 20.

A good finish will reflect light, of course, but the work will appear to be lacking in shine unless it is placed at exactly the right angle to reflect the light directly to the eye of the observer, as shown in Figure 21.

A general rule is that the clearer the image of the reflected light, the better will be the finish. In short, the lapper should attempt to produce a finish which resembles a mirror as closely as possible.

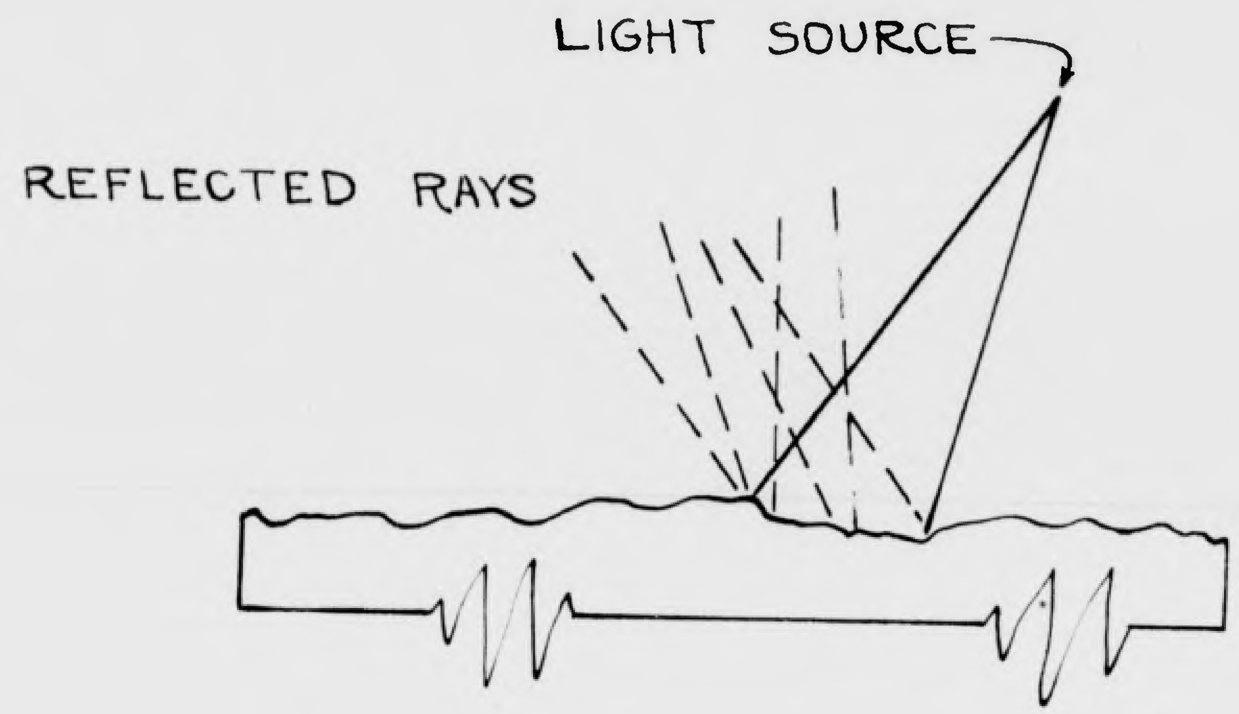

FIG. 20
POOR FINISH
SHINY APPEARANCE

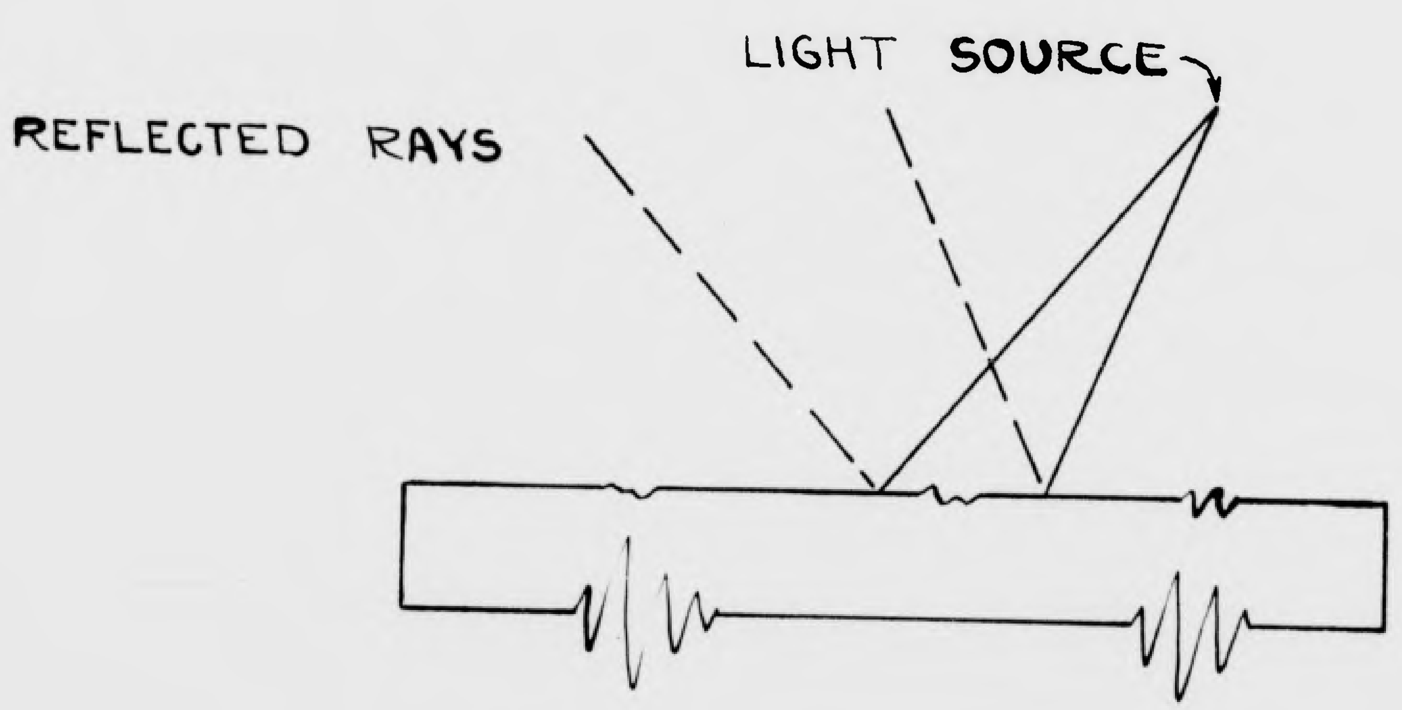

FIG. 21
GOOD FINISH
DULL APPEARANCE

TABLE V

FACTORS WHICH PRODUCE UNDESIRABLE RESULTS
IN THREAD LAPPING

RESULT	Rough Finish	Poor Thread Form	Slow Cutting Action
CAUSES	Coarse Abrasive	Worn Lap	Fine Abrasive
	Lap of hard material	Lap of soft material	
	Fresh abrasive	Worn abrasive	Worn abrasive
	Too much abrasive	Too much abrasive	
	Infrequent reversal of lapping motion	Infrequent reversal of lapping motion	Infrequent reversal of lapping motion
	Heavy working pressure		Light working pressure
	Lap not porous enough		Lap not porous enough
	Slow work speed		Fast work speed
	Oil of low viscosity		Oil of high viscosity
	Work of soft material		Work of hard material

TABLE VI

FACTORS WHICH PRODUCE DESIRABLE RESULTS IN THREAD LAPPING

RESULT	Smooth Finish	Good Thread Form	Fast Cutting Action
CAUSES	Fine abrasive	Accurate lap	Coarse abrasive
	Lap of soft material	Lap of hard material	
	Worn abrasive	Fresh abrasive	Fresh abrasive
	Rapid reversal of lapping motion	Rapid reversal of lapping motion	Rapid reversal of lapping motion
	Light working pressure		Heavy working pressure
	Fast work speed		Slow work speed
	Oil of high viscosity		Oil of low viscosity
	Work of hard material		Work of soft material

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CHAPTER VII

INSPECTING THREAD GAGES

Measuring Threads in a Machine Tool

In order to save time, and in order to reduce inaccuracies caused by disturbing the machine settings, it is desirable to measure threaded work without removing it from the machine until after the thread making operation has been completed.

This measurement is usually accomplished by means of micrometers equipped with special anvils. These anvils can be of two types: V shaped pieces which contact nearly the full flank of the thread, and ball points with diameters equal to the diameters of the "best size" measuring wires for the pitch in question. The latter type are to be preferred because they give readings which are independent of errors in the angle of the work.

Ball point micrometers do not give readings in terms of absolute size; they are merely comparators. The operator can ascertain the size of his work by subtracting the reading for a measured model from the reading for his work piece, and adding the difference to the known size of the model.

Considerable savings will be effected if models are kept in stock for all sizes of gages frequently made. These models should bear tags giving the basic size and the size of the model to the nearest ten-thousandth of an inch. In addition, models should have some identifying marks such as a nick in the shank or an M written in bluing.

In the case of infrequently manufactured sizes, the operator will have to make his own model. When this is done, the supervisor should check the size and initial the tag before the operator is allowed to continue with the order.

The model should be at the upper limit of the tolerance, then if an operator makes a piece somewhat smaller than he intended, it may still be within his tolerance zone.

Micrometers with V-shaped anvils will give an absolute size reading. However, even in this case, more accurate results will be obtained by the use of a model.

The following precautions should be observed in using ball point micrometers:

1. Make sure that the points are set straight in their sockets.

2. Make sure that the points are set very firmly so that they cannot possibly change their position in operation. The best method of inserting the points is to grasp them about the shank with a pair of pliers and to force them into their sockets with a slight twist.

3. Inspect ball points whenever a different pair are inserted. This is accomplished by turning the micrometer spindle slowly and observing the points under a glass. If the points are bent or out-of-round, they should be discarded or relapped.

4. Check the micrometer readings frequently by measuring the model.

5. Do not force the micrometer across the work. This will give an inaccurate reading in addition to wearing the points unnecessarily. The best way to take a reading is to move the micrometer back and forth perpendicular to the axis of the threads, tightening it until there is just barely a slight catch or drag as the anvils pass over the points at the ends of the diameter. If accurate results are to be obtained, it is essential to keep the micrometers exactly perpendicular to the axes of the work and of the model at all times, or at least to keep the micrometers at exactly the same angle to the axes.

Threads can also be measured in the machine by means of ordinary micrometers and three measuring wires. This method is somewhat more accurate than others, but it is more expensive because it uses more of the operator's time, and because the wires wear rapidly under these conditions.

In addition to micrometers for measuring threaded work while still in the machine, there is available a special device which employs annular ribbed rolls for gaging members and registers size by means of a dial indicator.

Operator's Final Check

It is often the practice to require thread grinders to give their work a final check by means of dial indicators which read directly to ten-thousandths and which are mounted in heavy fixtures intended to be placed on a bench. The operdition, models should have some identifying marks such as a nick in the shank or an M written in bluing.

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<u>Operator's Final Check</u>

It is often the practice to require thread grinders to give their work a final check by means of dial indicators which read directly to ten-thousandths and which are mounted in heavy fixtures intended to be placed on a bench. The operator should be sure that the piece has cooled before performing this operation.

This type of instrument can also be used to advantage for classifying gages in the inspection room or in other instances where rapid and quiet precise gaging of several pieces is desired.

The ball point type of gaging member is preferable to the roll type for checking gages.

The Three Wire Method

The three wire method is generally accepted in American industry as the standard system for the precise measurement of pitch diameter. This method should be used in the shop to measure all models, and to measure borderline cases which are not clearly within the tolerance limits. It should also be used in the inspection room for the final inspection of each piece.

Measurement by the three wire method should be performed with great care since any one of several apparently trivial mistakes can ruin the accuracy of the reading.

The following suggestions relate primarily to measurement by means of precision measuring apparatus such as a Light Wave Micrometer or a Supermicrometer. However, most of these points also apply to the use of ordinary micrometers.

1. Do not allow the work or any part of the measuring apparatus to be exposed to temperature extremes. In particular, do not allow the measuring apparatus to stand in the direct rays of the sun.

Final inspection should be performed in a room where the temperature is maintained constantly at 68° Fahrenheit. It is the practice of some concerns to allow gages to stand in the constant temperature room a week or more before the final inspection.

2. If the gage has not been lapped, prepare it by rubbing the major diameter with fine emery cloth, washing in gasoline, and drying with compressed air. Rubbing the major diameter is necessary in order to remove the grinding burr, which can sometimes prevent the anvils from resting directly on the wires.

3. Place a clean piece of paper between the anvils of the measuring machine and bring them together with 2½ pounds pressure. Slide the paper around until the anvils no longer leave any trace of dirt.

4. Be sure that the pressure regulator is set for two and one-half pounds if the threads are twenty pitch or coarser. A pressure of one pound is necessary if the pitch is finer than twenty. A pound and a half variation in pressure can produce a marked variation in the reading.

5. When using a micrometer which must be set, clean the gage block by sliding it over a clean paper. Place it between the anvils and tighten the anvils until the pressure is exactly one or two and one-half pounds. Slide the block around between the anvils and readjust the pressure if necessary. Adjust the scale of the measuring instrument.

The object of sliding the blocks between the anvils is to make sure that dirt is not present and to ascertain whether any low spots have been worn in the blocks.

As to the size of the block, use any block within one-half inch of the major diameter of the piece. A set of three blocks ($\frac{1}{2}$",1" and 2") should be sufficient for measuring all thread gages up to four inches in diameter.

Never set the scale merely by bringing the two anvils together at the zero point.

6. Clean the measuring wires by wiping them with paper and set them into position between the gage and the anvils. Do not handle the wires more than necessary, especially near their mid-section, in order to avoid errors due to heat.

7. Extreme care should be taken not to bend the wires in the least. This applies especially to wires for fine pitch threads.

8. In the case of horizontal anvils, remove the supporting stage so that the gage is held in place solely by the wires. If the weight of the gage is too great to permit this, place a small shaft, or other cylindrical object, between the stage and the work, pointing towards the operator. The gage will then be supported but will be free to tip right and left and to move to and fro in a sideways direction in order to adjust itself properly between the anvils.

9. Tip the gage about the axis of the anvils and rotate it a bit in order to seat the wires.

10. No rubber bands, threads, wires, or other supports should touch the wires while the actual measurement is made.

11. Touch each wire individually and make certain that it is snug. If not, try changing the position of the gage,

reburring the major diameter, or checking the wire size. This is very important.

12. Record the reading to five decimal places and subtract from it the constant given on the container for the wires. The result will be the pitch diameter, accurate to four decimal places. Care should be taken not to confuse the wire size with the constant.

13. In order to measure out-of-round, rotate the gage one-half turn, recording the pitch diameter at the high point and at the low point. The difference between these readings will constitute the degree of out-of-round.

14. In order to measure high-low, place the wires two or three threads higher and two or three threads lower than the position for the first reading. Any differences in the readings, other than that which would be expected because of the known taper of the work, constitute high-low.

15. In case best size wires for the pitch in question are not available, a reasonably accurate measurement can be made by use of wires intended for pitches of nearly the same size. To do this, compute the pitch diameter in the customary fashion using the constant given for the best size wires for the pitch of the work. Then compute the difference between the diameter of the best size wire and the size wire actually used and multiply by three. In case larger than best size wires are used, subtract this figure from the pitch diameter reading. If smaller wires were used, add this figure.

This operation is expressed mathematically by the following formula:

$$E = M_n - C_b + 3 (G_b - G_n)$$

Where E = Pitch Diameter

M_n = Actual Measurement over the nearest size wires (those actually used)

C_b = Constant for the best size wires

G_b = Diameter of the best size wires

G_n = Diameter of the nearest size wires

16. In order to check the size of a measuring wire, place it in the measuring machine with an anvil on one side and a hardened, ground and lapped cylinder .75" in diameter on the other side. The pressure should be that under which the wire is intended to be used.

17. The anvils of the adjustable measuring machine should be lapped occasionally, say every two or three days if the machine is used regularly. In order to find out whether the anvils need lapping, place a gage and measuring wires between the anvils in the position for measuring pitch diameter and slide the gage up and down. If there is any appreciable variation in readings, the anvils should be lapped.

Equipment for Measuring by the Three Wire Method

The pitch diameter of thread gages should be measured to an accuracy of .0001". In order to meet this requirement the measuring machine used should preferably be accurate to .000025" and should have provision for measuring with exactly one pound and exactly two and one-half pounds of pressure.

Specifications for measuring wires are given in "Screw Thread Standards for Federal Services, 1942", p. 202.

Block gages used to set the measuring machine may be of the "work" class.

Measuring Lead

The lead of thread gages should preferably be checked with an instrument capable of measuring to an accuracy of .000025".

In case precision measuring machines are not available, a general indication of the lead accuracy can be obtained by use of a dial indicator lead checking device manufactured especially for this purpose.

Lead can also be checked roughly by means of optical comparators.

Measuring Angles and Width of Roots

There are three satisfactory means whereby the angles and roots of thread gages can be checked: Optical comparators, measuring microscopes, and test tools. In any case, it should be possible to detect all angle errors greater than two minutes.

Optical comparators are advantageous in that they indicate the degree of error. In using a comparator, the operator should always make sure that the centers have been turned through an angle equal to the helix angle of the threads. He should also make sure that the centers are close enough together so that the gage will be held securely between them.

A magnification of about 60 times is the most convenient for measuring threads by this method.

In addition to the standard type of projector, there is available a bench model comparator with special work supports designed to speed up the classification and over-all inspection of thread gages.

Microscope type measuring machines also possess the advantage of indicating the degree of error. Although this device has been common in Europe for many years, it has not been used in this country until quite recently.

The test tool method of checking the angle and root consists in setting the work in a special fixture, placing a tool shaped in the thread profile into the thread groove, and observing variations between the form of the tool and the thread profile by means of a powerful jeweler's glass. The special fixture consists essentially of centers for holding the work, an electric light to illuminate spaces between the tool and threads, and a guide to support the test tool and to keep it at right angles with the work.

A general rule to follow in checking the angle with a test tool is that if no light appears between the side of the tool and the thread flank, or if slight pressure is sufficient to close the gap, the angle will be satisfactory.

For checking the root, a test tool whose point has been ground to a flat equal to the maximum permissible width of root is used. If light appears at the point of the tool, the root is satisfactory. If light appears on the flanks, the root is not satisfactory.

The degree of error can only be estimated, rather than measured by the use of test tools. However, this method has an advantage in that the equipment is less expensive than the equipment required for other methods of checking thread form.

Checking the angle by measuring with two different sizes of measuring wires is not recommended because it takes considerable time and because it does not necessarily reveal curvature or other imperfections in the form of the flank.

Checking the Pitch Diameter of Internal Threads

The pitch diameter of thread ring gages can be roughly measured before the work has been removed from the machine by means of a special dial indicator device or by means of an internal thread micrometer.

The operator should make his final inspection of the ring gage by screwing a plug gage into it.

There does not appear to be any instrument for laboratory grade measurement of internal threads available in this country at the present time. However, it might be possible to obtain an O.M.T. Horizontal Optimeter with special gaging members for measuring the pitch diameter of internal threads. This instrument is made in England.

Another way of making a precise measurement of internal threads is by means of gage blocks and three measuring balls. These balls should have the same diameter as measuring wires for the pitch in question (provided differences in compression are neglected).

Two of the balls should be placed in adjacent thread grooves, and the third should be placed directly opposite, in a manner analagous to the placement of three wires. A combination of size blocks is placed between the measuring balls and it is built by a trial and error method until the blocks fit snugly between the spheres.

The constants are the same as those used for the corresponding external threads. However, they should be added to the reading instead of subtracted.

Checking the Form of Internal Threads

The form of internal threads is checked by making a cast of the threads and then examining the cast in the same way that other external threads are examined.

The widely prevalent practice of making casts with hot sulphur is not recommended because the heat expands the gage and distorts the form of the threads.

One of the most satisfactory materials for making casts of thread gages is Plaster of Paris. The Army Ordnance Laboratory Instructions give the following directions for the use of this material:

"The best quality Dental Plaster of Paris should be used and it should be kept in air tight containers as moisture reduces its strength. To avoid corrosion of the gage, it is necessary to use a corrosion inhibitor in the water mixed with the Plaster of Paris. A solution of potassium dichromate ($K_2Cr_2O_7$ crystals) 40 grams ($1\frac{1}{2}$ ounces) to a quart of water will not corrode steel gages. The Plaster of Paris mixture should be mixed to the proper consistency and poured quickly into the threads. A mixture of 50 grams of Plaster of Paris to 40 cc of $K_2Cr_2O_7$ solution will give a good mix for most threads. An excess of the potassium

dichromate solution will weaken the cast. The cast can be pulled shortly after the heat of reaction is apparent. The cast will not distort appreciably for one-half hour after pulling, unless it has been in an excessive drying atmosphere."

In preparation for examination by this means, the ring gage should be thoroughly cleaned in gasoline and dried. If a corrosion inhibitor is not available, or if difficulty is experienced in removing the cast, the gage can be painted with a very thin coat of grease, such as a thin mixture of gasoline and vaseline, or petrolatum and colorless kerosene. Great care should be taken to make the coat of grease as thin and as smooth as possible.

Next, the gage is set up vertically, and the lower portion is clamped between two flat plates. The Plaster is mixed with water until the resulting liquid flows easily, and is then poured into the gage until the maximum depth equals about one-quarter of the diameter. If desired, a bolt, or other headed object, may be placed head first into the liquid in order to facilitate the removal and the handling of the cast after it is hardened. Giving the gage a sharp rap will also make removal of the cast easier.

When the cast is placed in the projector, the proper horizontal alignment can be obtained by placing a thin wedge under the cast and adjusting it so that the crests of the threads fall on the horizontal line drawn on the ground glass plate of the projector. The proper adjustment for helix can be obtained by twisting the cast until the shadows of the threads are made as narrow as possible.

The National Physical Laboratory recommends that casts of ring gages less than one-half inch in diameter be made of a dental wax which softens in hot water. They point out that the gage should be warmed a bit before the wax is pressed, in order to prevent sudden chilling of the wax. The wax should merely be softened, not melted.

Another substance which has been used with considerable success for making casts of internal threads is copper amalgam. The Army Ordnance Laboratory Instructions read as follows on this subject:

"Copper Amalgam, similar to silver amalgam in its properties, is used for making small casts in small parts such as 1/4" and 1/8" pipe plug ring gages. The amalgam is heated, crushed with mortar and pestle, the excess mercury squeezed out in a small piece of chamois and then worked into the plastic state. Anyone who has seen a dentist prepare silver amalgam for a filling will recall the working of the amalgam into the plastic state. A soft thread plug is made to fit the ring gage, it has two longitudinal slots 180° apart and the amalgam is rammed into these slots with sufficient force to enter the roots of the threads. The cast should harden over night and when the plug is removed, it will permit accurate measurement of lead angle and taper of the internal thread."

Standards for Measurement

Those making thread gages for the United States Army, or for use in inspecting threaded parts which are to be purchased by the Army, should use the following publications as sources of standards for the dimensions and forms of thread gages:

> "Screw Threads Standards for Federal Services, 1942". National Bureau of Standards Handbook H28, Price 35¢
>
> "Federal Specification for Gages; Plug and Ring, Plain and Thread." Federal standard Stock catalogue Section IV (Part 5), Aug. 23, 1932, Price 10¢
>
> "American Standard for Gage Blanks" U.S. Bureau of Standards, Commercial Standard CS8-41 Oct. 7, 1941 (A.S.A. B47-1941), Price 15¢

Copies of the above handbooks can be obtained by mail from the Superintendent of Documents, Washington, D. C.

> "Screw Thread Gages and Gaging" American Standards Association Standard B1-2-1941, Price 60¢

This handbook can be obtained by mail from the American Standards Association, 29 Wast 39th Street, New York, N. Y.

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American Machinist, Vol. 47, pp. 1065-73 Dec. 20, 1917.

APPENDIX I ---- ROUTING SHEET FOR THREAD PLUG GAGE

GAGE: 1/2"- 20 NF - 3 "GO"
MATERIAL: 5/8" Diameter #11 Tool Steel

OP. NO.	DESCRIPTION OF OPERATION	NOTES	MIN. EACH AVERAGE	HOURS SET UP	EACH
1	Hand Screw Machine Turn major diameter of thread, form taper, face, chamfer, center and cut off.	Leave .015 to .018" on thread diameter and .010 to .012" on taper to grind.	4.00	1.50	.067
2	Hand Screw Machine Face, chamfer and center other end.		1.50	.75	.025
3	Inspect				
4	Strain relieve, anneal	1200° slow cool to 800° (50° per hr.)			
5	Sand Blast		3.00	.25	.050
6	Cylindrical Grinder Rough grind major diameter of thread.	Leave .008" on diameter for finish grind.	1.80	.50	.030
7	Thread Grinder Rough grind thread.	Leave .015" on diameter for finish grind.	1.50	.75	.025
8	Special Machine Convolute	Cut thread back one full turn.	2.50	.75	.042
9	Special Machine (Roll Process) Stamp markings.				
10	Inspect				

APPENDIX I ---- ROUTING SHEET FOR THREAD PLUG GAGE (Continued)

OP. NO.	DESCRIPTION OF OPERATION	NOTES	MIN. EACH AVERAGE	HOURS SET UP	HOURS EACH
11	Harden	1480° brine (Minimum 5 min. each 1" cross section)			
12	Draw	235° 4 Hrs. Oil			
13	Sand Blast				
14	Test for Hardness	Hardness - 60 + on Rockwell C Scale			
15	Special Machine Lap Centers		3.00	.25	.050
16	Cylindrical Grinder Grind major diameter of threads to .003"	Leave .003" on diameter for finish grind.	1.20	.50	.020
17	Cylindrical Grinder Finish grind taper of shank		2.40	.50	.040
18	Draw	235° 4 Hrs. Oil			
19	Inspect				
20	Thread Grinder Finish grind thread		4.80	.75	.080
21	Draw	235° 4 Hrs. Oil			
22	Stabilize	212° 8 Hrs. Water			
23	Inspect				
24	Lap Threads				

APPENDIX I ---- ROUTING SHEET FOR THREAD PLUG GAGE (continued)

OP. NO.	DESCRIPTION OF OPERATION	NOTES	MIN. EACH AVERAGE	HOURS SET UP	HOURS EACH
25	Cylindrical Grinder Finish grind major diameter	Take very light cuts to avoid warping	2.00	.50	.033
26	Inspect				
27	Store				

APPENDIX I ---- ROUTING SHEET FOR HANDLE FOR THREAD PLUG GAGE

Gage: 1/2" - 20

Material: 1/2" Hex. 1020 C D or Die Casting

OP. NO.	DESCRIPTION OF OPERATION	NOTES	MIN. EACH AVERAGE	HOURS SET UP	EACH
1.	Universal Bar Machine Spot, drill half way, chamfer, ream, taper and cut off to length		3.75	1.20	.063
2.	Universal Bar Machine Spot, drill through, face, chamfer, and ream taper		3.25	.75	.054
3.	Table drill Drill 1/4" hole for drift		1.50	.50	.025
4.	Burr and stamp to print		3.00	.10	.050
5.	Inspect				
6.	Store				

APPENDIX II

Definitions of Terms Related to Screw Thread Gages and their Manufacture

ADJUSTING SLOT

A radial slot provided in adjustable thread ring gages to facilitate increasing and decreasing the size of the gage by means of an adjusting device.

ADJUSTING SLOT TERMINAL HOLE

The hole which always terminates the outer end of the adjusting slot.

ALLOWANCE

An intentional difference in the dimensions of mating parts. It is the minimum clearance or the maximum interference which is intended between mating parts. It represents the size difference of the tightest permissable fit, or the largest internal member mated with the smallest external member.

ANGLE OF TAPER, INCLUDED (B)

In tapered threads, the angle between the pitch line and any line parallel to the axis.

ANGLE OF THREAD (A)

The angle included between the sides of the thread measured in an axial plane. This is 60° for American National Thread.

ANNULAR

Arranged so as to be exactly perpendicular to the axis. Annular ribs or grooves are disc-like, rather than spiral. the term, when used in this sense, is generally used to describe the profile of the gaging section.

ANNULAR PLUG GAGE

A shell type plug gage in which the gaging member is in the form of a ring, the external surface of which is the gaging section, the central portion of the webbing machined away for the purpose of reducing weight, ball handles being provided for

Appendix II.

ANNULAR PLUG GAGE Cont'd.

convenience in handling. This construction is employed for thread plug gages in ranges above 8.01 inches. This type of gage has no relation to the term "Annular" as defined in the previous paragraph.

ANVIL

That portion of a micrometer or measuring machine which comes in actual contact with the work. Also, the non-adjustable gaging member of a snap gage.

AXIS OF A SCREW

The longitudinal central line through the screw.

BACK TRACK

The path followed by a cutting tool or grinding wheel on the return stroke.

BASE OF THREAD

The bottom section of the thread; the greatest section between two adjacent roots.

BASIC

The theoretical or nominal standard size from which all variations are made.

BLANK

A piece of metal which has been machined in the form of a thread gage, but upon which threads have not yet been formed.

CHATTER

Small radial ridges on the surface of a product, the immediate cause of which is vibration in the tool, grinding wheel, or machine tool.

CLIMB-CUT

The work traverse motion in which the cutter or grinding wheel is rotating in the opposite angular direction from the work. The surfaces of the wheel and work will be traveling in the same direction at the point where they actually make contact.

Appendix II

CONVOLUTING

The process of cutting back the threads at the ends of the work so that the thread starts will have a full form profile.

CREST

The top surface joining the two sides (flanks) of a thread.

CREST CLEARANCE

The space between the crest of a thread and the root of its mating thread.

DEPTH OF BASIC TRUNCATION (f)

In a thread having flats at the crests, the difference between the major radius of the thread in question and the major radius of a sharp V thread having the same pitch diameter. For American National thread, $f = p/8 \times .86603$.

DEPTH OF ENGAGEMENT

The depth of thread contact of two mated parts, measured radially.

DEPTH OR HEIGHT OF TRUNCATED THREAD (BASIC) (h)

Difference between the crest and root of truncated thread, measured perpendicular to the axis. For American National thread, $h = .649519 \times p$.

DEPTH OF SHARP V THREAD (H)

The distance between the crest and base of the thread measured normal to the axis.

DIAMOND LINES

In ground threads, these are circular ridges, usually few in number, which run along the thread flanks, following the helix of the thread. These are caused by uneven motion of the diamonds as they dress the grinding wheel.

Appendix II

DRESSING

The operation of drawing a diamond, or other hard tool, across the surface of a grinding wheel in order to renew the accuracy of the form and to remove dull abrasive grains.

DRIFT HOLE OR DRIFT SLOT

A small hole or slot provided in the side of a taper lock gage handle near the "go" end through which a pin or drift may be inserted for the purpose of e-jecting the gaging member from the handle.

EFFECTIVE DIAMETER

The English term for pitch diameter.

EXTERNAL THREAD

A thread on the outside of a member. Example: The threads on a bolt.

EXTERNAL THREAD GAGE

A gage for checking external thread. Such a gage generally bears internal threads itself. Example: A thread ring gage.

FINISH

The character of the surface of a product, especially as regards smoothness. In gage making, the term is often intended to relate to the imperfections caused by the nature of the tool or grinding wheel, as distinguished from the comparatively large "chatter" marks caused by vibration.

FIT

The relation between two mating parts with reference to the conditions of assembly. In other words, the degree of tightness existent when two parts are as-sembled. The quality of fit is dependent upon both the relative size and the quality of finish of the mating parts.

FLANGE

The external portion of a large ring gage which is reduced in section for the purpose of lightening the gage.

Appendix II

FLANKS

The surface of the thread which connects the crest with the root.

FLAT (F)

The crest or root of any thread which is not rounded. The width of basic flat at top, crest, or root = F = p/8 for American National thread.

GAGING MEMBER

The integral unit of a gage which is accurately fin-ished to size and is employed for size control of the work. In the case of a taperlock plug gage, the en-tire plug, including the shank, constitutes the gaging member, as distinguished from the handle.

GAGING SECTION

The portion of the gage which comes into physical con-tact with the work. In case of a taperlock thread plug gage, the threaded portion, not including the shank, constitutes the gaging section.

GO GAGE

A gage which can be mated with a satisfactory work piece. A go gage checks the maximum limits of ex-ternal surfaces and the minimum limits of internal surfaces.

HALF ANGLE (a)

One half of the angle included between the sides of the thread measured in an axial plane. This is 30° for American National Thread.

HELIX ANGLE (s)

The angle made by the helix of the thread at the pitch diameter with a plane perpendicular to the axis.

HUB

The mid-section of a flanged ring gage. It deter-mines the length of the gaging section.

Appendix II

INSPECTION GAGE

Gages used in the final inspection of the product.

INTERNAL THREAD

A thread on the inside of a member. Example: The threads on a nut.

INTERNAL THREAD GAGE

A gage for checking internal threads. Such a gage generally bears external thread itself. Example: A thread plug gage.

LEAD (L)

The distance a screw thread advances axially in one turn. On a single-thread screw, the lead and pitch are identical; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch, etc. $L = \frac{1}{N}$

LENGTH OF ENGAGEMENT (Q)

The length of contact between two mated parts, measured axially.

LIMITS

The extreme permissible dimensions of a part. The difference between the limits is the tolerance.

LOCKING SLOT

The slot which passes entirely through the wall of an adjustable thread ring gage. In conjunction with the thread ring gage locking device, it permits increasing and decreasing the gage size.

MAJOR DIAMETER (D)

The largest diameter of the thread of the screw or nut. In the case of external threads, this is the distance between the crests on opposite sides of the screw, measured perpendicular to the axis. In the case of internal threads, it is the corresponding distance between the roots. The term "major diameter" replaces the term "outside diameter" and "full diameter".

Appendix II

MAJOR RADIUS (d)

The radius corresponding to the major diameter.

MASTER GAGE

A gage used to determine the accuracy of other pages.

MECHANICAL GAGE

A gage made in the form of the part with which the work is to mate. The inspection is made by means of a trial assembly.

MINOR DIAMETER (k)

The smallest diameter of the thread of the screw or nut. In the case of external threads, this is the distance between the roots on opposite sides of the screw, measured perpendicular to the axis. In the case of internal threads, it is the corresponding distance between the crests. The term "minor diameter" replaces the terms "core diameter" and "inside diameter".

MINOR RADIUS (k)

The radius corresponding to the minor diameter.

NEUTRAL ZONE

A positive allowance. The intended space between the largest internal member and the smallest external member, when mated.

NOT GO GAGE

A gage which cannot be mated with a satisfactory work piece. A not go gage checks the minimum limits of external surfaces and the maximum limits of internal surfaces.

NUMBER OF THREADS PER INCH (n)

Number of threads in one inch of length, measured axially.

NUMBER OF TURNS PER INCH (N)

The number of revolutions which a screw makes in advancing a distance of one inch axially. For single

NUMBER OF TURNS PER INCH (N) Cont'd.

start threads, the number of turns per inch will be the same as the number of threads, for two start threads, the number of turns per inch will be one half of the number of threads per inch, etc.

NUT

For the sake of brevity, the term "nut" is often used to indicate any internal thread.

OPTICAL GAGE

A gage in which the work is visually compared with a master pattern. There are two types: those in which the image of the work is magnified by means of a microscope, and those in which the magnification is brought about by projecting the shadow of the work onto a screen.

PITCH (p)

The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. This should not be confused with the term "Pitch" as used to denote the number of threads per inch, as, for example, "20 Pitch thread". The symbol for "Pitch" when used in the latter sense is "Pi." The pitch in inches, p, $= \frac{1}{\text{number of threads per inch}}$.

For example, the pitch (p) of twenty pitch thread, so called, is $p = \frac{1}{n} = \frac{1}{20} = .050"$

PITCH DIAMETER (E)

On a straight screw thread, the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder. On a taper screw thread, the diameter, at a given distance from a reference plane, perpendicular to the axis of an imaginary cone, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cone.

PITCH LINE

An element of the imaginary cylinder or cone specified in the above definition. In other words, it is an imaginary line drawn across the thread profile in such a position that the thread flanks cut the line into equal segments.

PITCH RADIUS (e)

The radius corresponding to the pitch diameter.

PRE-THREADING

Refers to rough forming the threads on the blanks before hardening, in order to reduce the time required for finish grinding or lapping.

RELIEF

Grooves cut at the roots of gage threads in order to assure clearance for the crests of the mating threads. Relieved tap or hob threads, however, are threads which have been formed so as to be smaller in diameter at the heel (back part of the thread section) than in the area near the cutting edge. The purpose of this type of relief is to provide clearance from chips and to reduce friction.

REVERSIBLE OR TRILOCK PLUG GAGE

A plug gage in which three wedge-shaped locking prongs on the handle are forced into corresponding locking grooves in the gaging member by means of a single through screw, thus providing a self-centering support with a positive lock. When this type of gage becomes worn, the gaging member can be reversed, so as to use the unworn portion of the threaded surface. This design is standard for all plug gages in the ranges above 1.51 to and including 8.01 inches, with the exception of pipe thread plug gages for which it is standard in the ranges above 2 inch nominal pipe size, to and including 6 inch nominal pipe size.

ROOT

The bottom surface joining the sides (flanks) of two adjacent threads.

SCREW

For the sake of brevity, the term "screw" is often used to indicate any external thread.

Appendix II

SCREW THREAD

A ridge of uniform section in the form of a helix on the surface of a cylinder, or of a **conical spiral** on the surface of a cone.

SETTING GAGE

A thread plug gage which is used in adjusting adjustable external thread gages.

SHANK

The portion of a gaging member which is employed for binding the gaging member in the handle or frame.

SIDES

The surface of the thread which connects the crest with the root.

SNAG

A portion cut away from the grinding surface of a grinding wheel in order to reduce diamond wear and to shorten dressing time.

TANGENT OF HELIX ANGLE (S)

$$S = \frac{L}{\pi E}$$

TAPER LOCK PLUG GAGE

A plug gage in which the gaging member has a taper shank, which is forced into a taper hole in the handle. This design is standard for all plug gages in the range above .059 inch to and including 1.510 inches, and for pipe thread plug gages up to and including 2-inch nominal pipe size.

TEST TOOL

A gage which is exactly like the ordinary single point threading tool in form. It is thrust between the threads in order to check their form by comparison.

THICKNESS OF THREAD (t)

The distance between the adjacent sides of a thread measured along or parallel to the pitch line.

THREAD PLUG GAGE

A complete internal thread gage of either single or double-ended type comprising handle and threaded gaging member or members, with suitable locking means.

THREAD RING GAGE

An external thread gage employed for the size control of threaded work.

THREAD RING GAGE LOCKING DEVICE

This device provides a means of expanding and contracting an adjustable thread ring gage during the manufacturing or resizing processes. It is also an effective lock. It comprises an adjusting screw, a locking screw, and a sleeve.

TOLERANCE

The amount of variation permitted in the size of a part. Tolerance indicates the degree of accuracy which must be maintained in the manufacturing process.

TRILOCK PLUG GAGE

See "Reversable"

TRUING

The operation of shaping a grinding wheel to its proper form, when it is first mounted in the machine.

UP-CUT

The work traverse motion in which the cutter or grinding wheel is rotating in the same angular direction as the work. The surfaces of the wheel and work will be traveling in the opposite directions at the point where they actually make contact.

WORK GAGE

A gage used in checking a product as it is machined.

The definitions of gage elements are based on material given in "Gage Blanks."

The definitions of thread elements are based on material given in "Screw Thread Standards for Federal Services."

The letters in parentheses opposite some of the terms indicate the mathematical symbols usually employed to represent them.

APPENDIX III

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